AN ABSTRACT OF THE THESIS OF

Robert Matthew McDowell for the degree of Master of Science

in Agricultural and Resource Economics presented on September 20, 1977

Title: THE ECONOMICS OF CONTROLLING CATTLE FEEDLOT RUNOFF

Abstract approved: Redacted for privacy

Ray F. Brokken

A computer model is developed to estimate the initial investment and annual operating costs of feedlot runoff control systems. Costs are estimated for complete control systems consisting of a retention pond, settling basin, clean water diversion-runoff collection structures, disposal site, and an irrigation system. The model requires design inputs and cost inputs. Design inputs consist of: feedlot area, pumping rate, retention pond volume, disposal site area, and average pumping days per year. Cost inputs consist of market prices for system components and service costs.

The model is used to estimate the initial investment and annual operating costs of runoff control systems capable of complying with proposed Federal water pollution regulations for open beef feedlots. Design parameters for these systems are those developed by Wensink and Miner (1977).

Runoff control costs are estimated for one, ten, and 100 acre feedlots at seven U.S. locations. For the purpose of cost comparison, budgets are estimated for systems using: four different irrigation systems, 5 pumping rates, seven management alternatives, and two disposal policies.

The resulting data are analyzed to determine how investment and operating costs were effected by the following seven criteria: pumping rate, feedlot size, geographic location, management alternative, disposal policy, irrigation system, and operator convenience.

Estimated runoff control costs are compared to current costs of producing fed beef. The additions to current cost of production are estimated to be insignificant for larger feedlots (10-100 acres). Small feedlots (1 ac) face costs ($/head of capacity) ranging from three to ten times as high as those estimated for larger lots.

The second part of the analysis deals with the cost of controlling alternative levels of runoff, (lower than specified by federal regulations), at a specific site. Twenty systems, whose pumping rates and pond volumes represented 0, 5, 10, . . . , 100% of those necessary to meet federal standards, were budgeted for a 100 acre feedlot at Pendleton, Oregon. The cost data is compared to the performance of the systems, as measured by the percent of total runoff estimated to be controlled over the time period 1914-1971. A computerized watershed model developed by Wensink and Miner (1975) is used to simulate the performance (amount of runoff controlled) of the systems.

The resulting cost-performance data indicate significant cost reductions can be achieved with only minor increases in uncontrolled runoff. A 5% increase in uncontrolled runoff is coupled with a 25% reduction in required investment; increasing uncontrolled runoff by 10% results in a 40% reduction in required investment.

The Economics of Controlling Cattle Feedlot Runoff

by

Robert Matthew McDowell

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed September 1977

Commencement June 1978

APPROVED:

Redacted for privacy

Associate Professor of Agricultural and Resource Economics (Courtesy)

in charge of major

Redacted for privacy

Head of Department of Agricultural and Resource Economics

Redacted for privacy

Dean of Graduate School

Date thesis is presented September 20, 1977

Typed by Clover Redfern for Robert Matthew McDowell

ACKNOWLEDGMENTS

I wish to express my sincere thanks to Dr. Ray Brokken, my major professor, for his advice, guidance, and pertinent criticisms throughout my graduate program. I would also like to thank Dr. Frank Conklin and Dr. Richard Towey for their contributions.

A number of persons from the Department of Agricultural Engineering, Oregon State University, have aided materially in the completion of this thesis. I wish to thank Dr. J. Ron Miner and Dr. Robert Wensink for their good humor, patience, and financial support. A special thanks goes to Dr. Marvin Shearer for providing me with a short but excellent education in irrigation practices, and for his assistance in obtaining cost data. Thanks also go to Dr. John Wolfe for his assistance in deriving energy requirements of various irrigation systems. I would also like to thank Mr. Tom Booster for his excellent assistance in writing the computer program.

A special thanks goes to Ms. Carol Schonbrod who graciously and competently typed portions of the preliminary draft on short notice.

TABLE OF CONTENTS

Chapter		Page
I.	INTRODUCTION	1
	Problem	1
	Purpose and Scope of Study	2
	Review of Literature	3
	Externalities	3
	Pollution Control Laws	8
	Public Law 92-500	11
	Engineering Design Studies	14
	Beef Feedlot Industry	15
	Economics of Pollution Control	19
II.	FEEDLOT RUNOFF: CHARACTERISTICS OF POLLUTANTS AND RUNOFF CONTROL TECHNOLOGY	22
	Pollutants in Feedlot Runoff	22
	Runoff Control Technology	25
III.	RELEVANT ECONOMIC THEORY AND RESEARCH METHODOLOGY	31
	Theory of the Firm	31
	Application of Economic Theory to the Problem of Runoff Control	38
	Research Methods	40
	Statistical Estimation	40
	Survivorship Approach	42
	Synthetic Method	43
IV.	COST ESTIMATING MODEL	45
	Function of Model	45
	Model Inputs	46
	Design Inputs	47
	Cost Inputs	52
	Program Design	52
	Investment Items	54
	Earthwork	54
	Retention Pond	54
	Settling Basin	58
	Clean Water Diversion	59
	Land Occupied by Structure	60
	Retention Pond	60
	Settling Basin	61
	Diversion and Collection Terraces	62
	Disposal Site	62

Chapter		Page

	Irrigation Systems	63
	Sprinkler Units	63
	Hand Move	63
	Side Roll	65
	Stationary Big Gun	66
	Traveling Big Gun	67
	Pumps	69
	Mainline	72
	Miscellaneous Items	74
	Fencing	74
	Seeding and Erosion Control	74
	Engineering	74
	Settling Basin Check Dams	75
	Annual Operating Costs	75
	Interest and Depreciation	75
	Repair and Maintenance	77
	Taxes	77
	Labor	77
	Hand Move	78
	Side Roll	79
	Stationary Big Gun	80
	Traveling Big Gun	80
V.	MODEL OUTPUT AND ANALYSIS	83
	Model Output	83
	Interpretation of Output	94
	Storage Volume vs. Pumping Capacity	94
	Economics of Size	96
	Geographic Location	97
	Management Alternatives	99
	Disposal Policy	100
	Irrigation Systems	101
	Operator Convenience	102
	Added Costs to Producing Fed Beef	103
	Runoff Control Costs at Varying Levels of Control	105
VI.	SUMMARY AND CONCLUSIONS	114
	Pumping Rate of Disposal System	115
	Feedlot Size	115
	Geographic Location	115
	Management Alternatives	116
	Disposal Policy	116
	Irrigation Systems	117

Chapter	Page
Convenience of Operation	118
Added Production Costs	118
Cost vs. Pollution Control Achieved	119
BIBLIOGRAPHY	120
APPENDICES	123
Appendix A: Supporting Tables	123
Appendix B: Cost Estimating Model	129

LIST OF FIGURES

Figure		Page
1.	Hypothetical short-run and long run average cost curves.	37
2.	Block diagram of runoff control cost model.	53
3.	Cross-section of retention pond earthwork.	54
4.	Retention pond configuration.	55
5.	Block diagram of feedlot runoff model.	107
6.	Flowchart of feedlot runoff retention return period design model.	108
7.	Block diagram illustrating the combination of output from runoff control cost model and return period design model.	110
8.	Simulated cost and performance of feedlot runoff control systems at Pendleton, Oregon for time period 1914-1971.	111

LIST OF TABLES

Table		Page
1.	Beef feedlot industry structure and estimated methods and costs of runoff control.	21
2.	Feedlot runoff disposal systems.	30
3.	Climatic attributes of selected feedlot locations.	48
4.	Physical interpretation of the seven runoff management dewatering alternatives.	50
5.	Settling basin dimension and surface areas.	62
6.	Labor requirements for operating various irrigation systems.	78
7.	Annual pollution control cost (dollars per head of capacity) at Ames, Iowa as a function of pumping capacity, feedlot size, and management alternatives.	84
8.	Annual pollution control cost (dollars per head of capacity) at Lubbock, Texas as a function of pumping capacity, feedlot size, and management alternative.	85
9.	Annual pollution control cost (dollars per head of capacity) at Ames, Iowa as a function of pumping capacity, irrigation system, and feedlot size.	86
10.	Annual pollution control cost (dollars per head of capacity) at Experiment, Georgia as a function of pumping capacity, irrigation system, and feedlot size.	87
11.	Annual pollution control cost (dollars per head of capacity) at Lubbock, Texas as a function of pumping capacity, irrigation system, and feedlot size.	88
12.	Annual pollution control cost (dollars per head of capacity) at Pendleton, Oregon as a function of pumping capacity, irrigation system, and feedlot size.	89

Table	Page
13. Minimum annual pollution control cost (dollars per head of capacity) for various disposal policies for Ames, Iowa and Lubbock, Texas.	90
14. Annual pollution control costs (dollars per head of capacity) when pumping ten or fewer days per year for various irrigation systems at seven U.S. locations.	91
15. Minimum investment and annual pollution control costs (dollars per head of capacity) at seven U.S. locations.	92
16. Annual pollution control costs (dollars per head of capacity) at seven U.S. locations with similar pumping capacities.	93
17. Added production cost (dollars per head) associated with pollution control systems as a function of feedlot size and location.	94
Appendix	
1. Cost parameters used in model to generate output data.	124
2. Components costs of continuously moving big guns.	125
3. Calculation of present value of traveling big gun and necessary hose replacements.	125
4. Specifications of pumps for hand move and side roll systems.	126
5. Specifications of pumps for stationary and traveling big gun systems.	126
6. Pump component costs.	127
7. Aluminum mainline sizes, capacities, and costs.	127
8. "Big gun" nozzles: discharge rates, wetted radii, and application rates at 100 psi operating pressure.	128

THE ECONOMICS OF CONTROLLING CATTLE FEEDLOT RUNOFF

I. INTRODUCTION

Problem

For society as a whole, some balance between fed cattle production and cattle feedlot runoff can be described as optimal. The federal government has defined the optimal level of feedlot runoff with a set of standards specifying the conditions when cattle feedlots may legally allow runoff to leave the feedlot. The standard has been set in terms of a level of performance any feedlot runoff control system must achieve. The use of a performance standard (as opposed to a design standard) allows for considerable flexibility in selecting control methods. It also raises a number of questions about the effects of implementing such a standard: What are the costs of complying with the standard? Will the standard impact on all operations in the same way? What are the effects on various sizes of feedlots? Will some regions be placed at a competitive disadvantage due to imposition of the standard? What are the costs--and benefits--of alternative standards?

The current situation can be better understood when placed in its historical perspective. The following sections of this chapter will trace the development of some of the theoretical and institutional approaches to the problem of pollution control. The current standard will be described in detail and the structure of the beef feedlot industry will be examined. In addition, the existing studies on the potential effects of the standard on the industry will be reviewed.

Purpose and Scope of Study

The basic purpose of this study is to generate data on the costs of controlling runoff from beef cattle feedlots. Costs will be generated with respect to controlling runoff in order to comply with the guidelines established by the Environmental Protection Agency in furtherance of the Federal Water Pollution Control Act Ammendments of 1972.

A computerized cost estimating model will be constructed to generate the costs. Costs will be estimated for feedlots at seven locations in the United States for full compliance with the regulations. At each location, costs will be generated with respect to:

1. A number of different pumping rates and pond volumes;
2. Eight management alternatives (timing of disposing of effluent);
3. Four different irrigation systems to dispose of effluent;
4. Three feedlot sizes; and,
5. Two different approaches to waste disposal.

This information will hopefully be of value in assisting regulatory agencies to assess the impact of the proposed guidelines on the feedlot industry in general, specific segments of that industry, and on the general public as a consumer of beef. The information generated should prove of value to feedlot operators in assessing the costs of various management alternatives and types of control systems.

The cost estimating model will be used to generate the costs of levels of control other than that specified by the EPA regulations. This data will be used to generate a cost curve for the control of runoff at one site. With this data will be presented the estimated amount of runoff at each level of control to provide some cost-benefit relationships at different levels of control.

Review of Literature

Externalities

Air and water have historically been considered "common property" resources, available for use by all, essentially free of charge. As free goods, they have long been used as repositories for the waste products of biological and industrial activity. Until recent years, human population levels and the technologies used by those populations did not seriously overload the capacity of our air and water resources to assimilate these materials. However, since the industrial revolution, human populations have grown rapidly. As both cause and effect of this growth, technical innovation has raised the standard of living for much of the world, increasing our use of some resources. The technologies responsible for this increased output of goods and services (increased resource use) have caused a general reduction in the quality of our environment.

While air and water are crucial commodities, no market exists where the various consumers of these resources can indicate their preferences (with respect to price) to effectively allocate these resources. Firms, individuals, and communities have used these free goods (air, water, and soil) as waste sinks, in many cases to the point of abuse. The overutilization of the environment to assimilate wastes is guaranteed by the institutional framework that governs the use of these commodities: There is little or no charge to individuals using these resources as a waste sink. While the benefits from such use are not necessarily distributed equally, both society as a whole, and polluters have benefited from the availability and use of these free resources.

The absence of a market to effect the allocation of these resources has contributed to the situation where some individuals suffer a reduction in the quality of life due to the activities of other groups or individuals. This broad class of activities is referred to by economists as "externalities". As defined by Randall (1972), an externality occurs

> whenever the utility of one or more individuals is dependent upon, among other things, one or more activities which are under the control of someone else.

An external diseconomy is defined as the condition where the utility of one or more individuals is reduced by the activities of others not under their control.

Any reduction in the generation of external diseconomies requires some instrument to alter the behavior of those creating them. In his review of the problem, Mäler (1974) lists three basic types of solutions proposed by economists:

1. Market solutions[1/]
   a. Those creating the externality must compensate the individuals affected, i.e., "bribe" them to accept the externality, or;
   b. Those affected by the externality would bribe the party generating the externality to induce them to reduce production or change technology.
2. Unit charge, taxes, or subsidies applied to the externality, proportional to the damage they create. Revenues collected

---

[1/] For a more extensive treatment of market solutions to externality problems, see "The Problem of Social Cost," Journal of Law and Economics, Oct. 1960, by R.H. Coase.

could be turned over to the affected party(s) or returned to the group producing the externality in the form of a subsidy on control measures; some propose taxing both the creators of the externality and those affected by it.

3. A set of standards that set a limit on the generation of externalities.

All the solutions have imperfections, but most economists have favored market solutions or taxes/charges as being more efficient (Randall, 1972). Kneese (1968), however, has raised objections to the use of market solutions to the problem of allocating common property resources, on the basis of high transaction costs as a barrier to effective allocation.

The generation of external diseconomies confers benefits to some, costs to some, and both benefits and costs to others. The distribution of the costs is by no means uniform; Alvin Kneese (1964) has hypothesized that in most cases, the entire resulting damages and costs are external to the unit creating the environmental pollution. On the other hand, in many cases, the benefits accruing from the use of the environment as a waste disposal site or system have been widespread in the form of lower priced goods and a larger aggregate disposable income.

The evaluation of the distribution of costs and benefits (utility and disutility) is the province of welfare economics. Any change in the production of externalities will change the distribution of utility and disutility in a society, and thus becomes a welfare issue. As the prospect of zero pollution has no meaning, some balance must exist between the production of all goods and the use of the environment to assimilate the residuals of production and consumption. The fact that government is seeking to change the current balance (with the implicit approval of the general public) suggests that it may be sub-optimal, i.e., the total costs may exceed the total benefits. Social welfare might be increased by reducing the discharge of pollution.

The extent to which pollution should be controlled is less clear. As pointed out by Dorfman and Jacoby (1971), this is largely a matter of personal values and what ought to be done is judgemental, so legitimate differences of opinion will exist. Arrow (1963) has also theorized there is no way a personal evaluation function can be summed into an aggregate social welfare function to give a unique answer to the question of whether resource allocation A is better than allocation B. In any event, the limits to water quality improvement are and will be essentially economic--to what extent limited resources will be devoted to improving and maintaining water quality (Kneese, 1964).

Until the development of the modern feedlot industry, livestock production in the U.S. created few waste related external diseconomies of serious concern. Cattle were raised mainly on pasture and range, and the manure produced was easily absorbed by the environment. Changes in production practices to more intensive methods have concentrated animals and their waste products on smaller land areas. This has resulted in the generation of external diseconomies affecting other users of watersheds used by feedlots to dispose of wastes.

The federal government has responded to the general desires of our society to remedy this situation. A standard has been imposed limiting the discharge of pollution from feedlots except in conjunction with catastrophic rainfall events (Wensink and Miner, 1975). If a standard is used <u>efficiently</u> to define the acceptable level of pollution, it must be based on the costs and benefits of meeting that standard, both in total <u>and</u> at the margin (Coase, 1960). At the present time, the total cost of complying with the EPA runoff guidelines have been estimated for the U.S. beef feedlot industry. However, no analysis has been done on the marginal cost of runoff control at various levels of control. Further, no assessment has been made of the economic benefits of reducing feedlot runoff, either in total or at the margin.

Pollution Control Laws

The active involvement of federal and state governments in the control of water pollution is a relatively recent phenomenon--as is the widespread concern for the quality of the environment. In view of the attention environmental concerns receive today, it is hard to remember that as recently as 1960, pollution was not regarded as a serious problem. In that year, the President's Commission on National Goals, charged with identifying the 15 issues most in need of national concern and action, did not include controlling environmental pollution (Kneese and Schultze, 1975).

Federal interest in the quality of surface waters goes back to the 19th century; the 1889 Refuse Act was the first federal law aimed at limiting the discharge of pollutants into the environment. That act was aimed specifically at navigable waters, and prohibited the discharge of any material into any navigable water without a permit issued by the Chief of the U.S. Engineers. This was a very strict regulation--as a result it was virtually unenforced until the 1970's (Kneese and Schultze, 1975). 2/

After over half a century of public indifference to the question of water pollution control, authority was transferred to state governments with the passage of the Water Pollution Control Act of 1948 (Kneese and Schultze, 1975). Passage of the Federal Water Pollution Control Acts Amendments of 1956 (Kneese and Schultze, 1975)

2/ The predictable effect of passing an essentially unworkable law is that it will be ignored. The French also had very strict regulations that virtually prohibited the discharge of municipal sewage into rivers and streams; once again a tough law which went unenforced for two centuries (Kneese, Ayres, and D'Arge, 1970).

showed a new commitment on the part of the federal government to enter into the control of water pollution. This act established federal policy toward water pollution control, provided funds for constructing sewage treatment plants and established procedures for enforcing the guidelines.

During the period 1956-1972, several states enacted laws regulating the discharge of pollutants into surface waters. One of these states, Kansas (Klocke, 1976), passed a law specifically addressed to the problem of runoff from beef cattle feedlots. Runoff following storms deposited large amounts of pollutants in surface waters and resulted in several serious pollution episodes involving fish kills. In response to the public reaction to these events, regulations were imposed on feedlot operators, requiring some provision for controlling runoff.

The Kansas law required each feedlot operator to have some structure(s) capable of intercepting and storing a volume of runoff equal to the volume of a 24-hour storm event having some predetermined probability of occurring. This type of regulation, specifying a certain design standard, was convenient for both the feedlot operators and the regulatory agency, as it stated very clearly what was expected.

Public Law 92-500

In 1972, the Federal Congress passed the "Federal Water Pollution Control Act Amendments of 1972" which have as their expressed objective: "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." As part of this objective, the Amendments (Public Law 92-500) established two goals:

1. that the discharge of pollutants into the navigable waters be eliminated by 1985;[3/]
2. that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish and wildlife and provides for recreation in an on the waters be achieved by July 1, 1983.

The Amendments identified a number of industries as point sources of pollution. Concentrated animal feeding operations were one of the industries so specified. To meet the goals as described, the industries identified as point sources of pollution were enjoined from discharging any pollutants into receiving waters, unless done under a permit issued by the Environmental Protection Agency. Permits were to be issued only where the level of pollution reduction resulted from:

[3/] Material quoted on this and the following page is exerpted from the Federal Water Pollution Control Act Amendment of 1972, Public Law 92-500, 92nd Congress.

1. the application of the best practicable control technology currently available as defined by the Administrator by July, 1977;
2. the application of the best technology economically achievable for any such category or class by July, 1983.

In addition, the Amendments specified that the effluent guidelines would be reviewed at least every five years, and revised as necessary to reflect any changes in the "best technology economically achievable." Penalties for "any person who willfully or negligently violates" the regulations were set at:

> a fine of not less than $2,500 nor more than $25,000 per day of violation or by imprisonment of not more than one year, or by both. Limits of the fines or prison terms are doubled on the second conviction.

The Environmental Protection Agency was directed to develop effluent discharge limitations for the industries identified as major industrial sources of point pollution. The agency was also responsible for defining each industry for the purposes of specifying who would be required to comply with the law. The initial definition of a "concentrated animal feeding operation" (with respect to beef feedlots) was any facility with a one-time capacity of 1000 head or over. Due to the size distribution in the feedlot industry (see the following section on the structure of the feedlot industry), this definition excluded about 99% of the total feedlots in the United States from any federally imposed effluent limitations. This definition was successfully challenged in court by the National Resource Defense Council

(NRDC vs. Train), and the EPA was ordered to revise their definition of a concentrated animal feeding unit (USDA, 1976).

The revised regulations required any person discharging or proposing to discharge pollutants from a concentrated animal feeding operation to apply for a permit to do so by March of 1977. The new regulations defined a "concentrated animal feeding operation" to mean those operations where:

> (i) Without regard to the numbers or types of animals confined, measurable wastes are discharged into navigable waters through a manmade drainage ditch, a flushing system, or other similar manmade device; or
> (ii) without regard to the numbers or types of animals confined, measurable wastes are discharged directly into navigable waters which originate outside of and traverse the operation; or
> (iii) more than the following numbers and types of animals are confined: (A) 1,000 slaughter or feeder cattle. 4/

In developing the guidelines that would insure compliance with the 1977 and 1983 dates, the EPA modified the approach of the Kansas feedlot pollution control law. For the 1977 deadline, effluent guidelines defined the level of control at the 10 year-24-hour storm; the 25-year 24-hour storm value was set for the 1983 limit. These values were established as <u>performance criteria</u>, not design criteria as originally used in the Kansas law. Thus, feedlot operators could no

---

4/ Limits were set for other types of livestock, but are not relevant to this discussion. Animal numbers specify one-time capacity.

longer build retention facilities of volume equal to a given storm size. The new guildelines defined as illegal any runoff resulting from a storm event of magnitude less than the relevant storm size as specified in the 1977 and 1983 goals. This subtle distinction caused considerable confusion as there were no design criteria available that would insure this level of control. While this provided more flexibility in the way an operator could choose to comply with the law, the primary responsibility for designing facilities that would comply with the law was shifted to the operator. In response to the need for actual design criteria and evaluation of previous design criteria as potential use under the new regulation, studies were undertaken by a number of agricultural engineers.

Engineering Design Studies

The first studies undertaken tested the performance of the design standards used in the early state regulations. Computer simulated watersheds were used to evaluate the existing design standards in light of the proposed EPA regulations. This work by Larsen, et al, (1974) and Koellicker, Manges, and Lipper (1975) showed that for the Midwest and North Central states, the existing design standards were not sufficient to comply with the new law. Both studies showed that the large volume storm that occurred infrequently had little impact on the performance of systems, but that chronic wet periods were the controlling factor.

Wensink and Miner (1975) developed a computer simulation model of a feedlot surface which used historic weather data to predict the performance of runoff control systems. This model, called the Return Period Model, was used to test the performance of various runoff control systems whose parameters were based on the 10 year-24 hour storm, and the 25 year-24 hour storm at several Oregon locations.

These were found for the most part to be insufficient. A program was then developed which utilized historic weather data to develop design parameters for systems which would control the requisite amount of runoff. This model was expanded by Wensink and Miner (1977) and used to derive design parameters (sufficient to meet 1983 EPA standard) for runoff control systems operated under a number of different management policies for seven locations in the United States.

Beef Feedlot Industry

The beef feedlot industry in the United States is concentrated in 18 states. These 18 states account for about 98% of all U.S. feedlots and approximately 95% of the total fed beef marketings (Johnson, et al, 1975). The industry is comprised of essentially two types of firms: 1) farmer-feeders, who usually feed a relatively small number of cattle using feed raised on-farm, and 2) commercial feeders, who usually buy both feeder cattle and feed from off-farm sources. The total number of farmer-feeders greatly outnumber commercial feeders. Feedlots with capacity of less than 1000 head comprise 99% of all feedlots and produce about 35% of the total fed beef output, with the remaining 1% of the lots with capacity over 1000 head producing about 65% of the total fed beef (Development Planning and Research Consultants, Inc., 1974).

The geographical distribution of the various sizes of feedlots is not uniform. The majority of the small feedlots are in the midwest and north central states. In 1969, the state of Iowa had over 42,000 feedlots with capacity of less than 1000 head, including 33,000 feedlots with one-time capacity of less than 100 head. At that date, the five major western states[5/] had a total of only about 3500 feedlots with capacity of less than 1000 head (Johnson, et al, 1975).

The western states have most of the large feedlots. In 1974, 13 western states[6/] accounted for over 97% of the fed cattle marketed in the U.S. from feedlots with capacities of over 2,000 head. These

---

[5/] Oklahoma, Texas, Colorado, California, and Arizona.

[6/] South Dakota, Nebraska, Kansas, Oklahoma, Texas, Colorado, New Mexico, Arizona, California, Oregon, Washington, Idaho, and Montana.

feedlots accounted for 57% of the total fed beef marketings in the United States in that year (Gee, 1976).

The trend is also toward more large feedlots. In the time period from 1965 to 1973, the following changes occurred in the marketings from western beef feedlots:

(i) lots with one-time capacity of 2000-3999 head reduced marketings by 5%;

(ii) lots with one-time capacity 16,000-31,999 increased marketings by 144%;

(iii) lots with one-time capacity of over 32,000 head increased marketings by 963%.

In this same period, the total number of small feedlots in the rest of the beef feeding states decreased. The long run trend has been to bigger feedlots, fewer smaller ones, and a regional change in the areas of production.

Gee (1976) also described the waste management practices of western feedlots in detail. Data was gathered through interviews with 238 feedlot operators (representing 23% of the total feedlots with one-time capacity of 2,000 head or more) in the 13 western states containing 88% of all feedlots that size in the United States. Fed cattle marketed from lots this size in the 13 states accounted for 57% of the total fed cattle marketings in the U.S. in 1973 and 97% of all cattle marketed from feedlots of this size. Lots of this capacity accounted for 76% of all fed cattle marketings in the 13 western states.

Surface water runoff control structures were found on 74% of the feedlots surveyed by Gee. Forty-nine percent of the lots surveyed had settling ponds or ditches, 80% had retention ponds, and 58% has irrigation equipment to empty runoff holding ponds. Eighty-three percent of the largest lots (capacity 32,000 head and over) had runoff control structures compared to only 50% of lots capacity 2,000-3,999.

Feedlot size was found to have an effect on pumping policies. Frequency of pumping is correlated to feedlot size; 60% of lots with capacity 2,000 to 3,999 never emptied retention ponds, while only 14% of the largest lots (capacity greater than 32,000 head) followed this policy. The majority of all feedlots in all size classes emptied ponds less than four times per year.

Of those lots which did empty ponds, 51% used irrigated cropland for the disposal site. The other lots used wasteland or privately owned ponds or lakes for disposal. Only small acreages were used as disposal sites; the largest disposal site discovered in the study was 11 acres.

The investment in feedlot runoff control structures in existence is substantial. The average investment for all feedlot sizes was $32,440. This is $2.12 investment per head of capacity. Investment per head of capacity ranged from $2.38 for lots of capacity

2,000-3,999 to $1.48 for lots with capacity 32,000 head and over.

No data are available for lots with capacity less than 2,000 head.

Economics of Pollution Control

When analyzed as a "production activity", pollution control exhibits some anomalous behavior: the marginal cost curves associated with pollution control are strictly increasing--they do not have the traditional "u-shape" associated with normal firm cost curves (Kneese and Schultze, 1975). This means there are no economies to be achieved by increasing the level of pollution control for a given amount of product produced. The unit cost of pollution control increases with every increase in control for a given firm size. As an example of this fact, the total costs of eliminating 85-90% of water pollution in the United States has been estimated at $61 billion; the cost of increasing this to 95-99% reduction in water pollution would be an additional $58 billion (Kneese and Schultze, 1975).

Several studies of the potential aggregate costs imposed on the feedlot industry by compliance with EPA runoff guidelines were made prior to the revision of the regulations. Due to the changes in the number of feedlots subject to compliance, the studies will not be discussed in detail. However, these studies showed most of the cost would fall on small feedlots in the midwest and north-central states.

These studies also showed significant economies of size would exist, particularly for western feedlots.

Johnson, et al, (1975) estimated an average investment per head of capacity of $21 for lots with capacity of 100-200 head. The estimated investment per head for lots with 1000 head or more was $3. For western feedlots with capacity of less than 1000 head, the estimated investment per head was $22. Larger western lots would face costs from $1-$4.

Following redefinition of the type of operations subject to compliance with effluent discharge guidelines, the United States Department of Agriculture (1976) issued a study that provided estimates of the costs of complying with EPA runoff guidelines. Table 1 presents a summary of the information contained in that report which pertains to the beef feedlot sector. As seen from Table 1, the major portion of the cost falls on the small feedlots, presumed to be mostly farmer-feeders. Of the total estimated capital cost of $25 million for the beef feedlot industry, 71% is accounted for by feedlots with capacity less than 1000 head, and 45% is accounted for by feedlots of less than 100 head capacity. While the costs are large, the report suggests that the total investment required to comply with the EPA guidelines is insignificant with respect to the total existing investment in feedlot facilities. The additional annual operating costs were also judged to be insignificant with respect to the total estimated value added in the beef feedlot sector of $10 billion annually.

Table 1. Beef feedlot industry structure and estimated methods and costs of runoff control.

	Operation Capacity (head)					
	<100	100-199	200-299	399-999	>1000	Total
Beef feedlots in U.S. (1,000)	102.3	11.2	3.7	8.3	1.7	127.2
Feedlots reqd. to comply with PL-92500	10,030	1,530	490	1,070	610	13,730
Total feedlots estimated to use following methods of control:						
Diversion	2,810	290	90	120	40	3,350
Gravity flow	3,370	580	160	330	140	4,580
Pump-irrigation	2,900	530	200	570	410	4,610
Relocation	950	120	40	50	20	1,190
Capital outlays reqd. for control ($ million)	11.5	2.4	1.1	3.2	7.4	25.6
% of total fed beef marketing from affected feedlots	0.9	0.9	0.6	1.7	16.1	20.2

Source: U.S.D.A. Animal Waste Subcommittee Report, Jan. 30, 1976.

II. FEEDLOT RUNOFF: CHARACTERISTICS OF POLLUTANTS AND RUNOFF CONTROL TECHNOLOGY

Cattle feedlot runoff has been regarded as a serious problem for only about 20 years. In the last ten years, a serious research effort has been made to assess its impact and to develop engineering solutions capable of bringing feedlots into compliance with federal and state water pollution guidelines. In this time, the problem has been documented extensively. Estimates of the pollution potential of feedlot runoff have been reported and considerable literature is available on the engineering approaches to reducing pollution from feedlot runoff. This chapter will briefly summarize the results of this research.

Pollutants in Feedlot Runoff

Runoff from open cattle feedlots is quite variable in its pollution potential, but is basically a highly concentrated waste containing soil sediments, organic materials, various inorganic chemicals, and microorganisms (Miner and Smith, 1975). The concentrations of pollutants is normally of a magnitude that makes treatment by conventional sewage treatment techniques or diversion to surface waters impractical.

Severe impacts on water quality can occur when surface waters are contaminated by feedlot runoff. The high concentration of organic material normally present in feedlot runoff places a heavy demand on the oxygen present in receiving waters. In many cases, the organic material so overloads the assimilative capacity of the stream or lake that dissolved oxygen concentrations are reduced to zero, causing death to any oxygen requiring organisms. Fish kills resulting from reduction in oxygen in streams and rivers that received feedlot runoff following storm events were some of the first events that brought the problem of feedlot runoff to the public attention.

In addition to the organic material present in feedlot runoff, it contains a number of inorganic chemicals that can have adverse effects on surface waters. Considerable amounts of nitrogen and phosphorus in a variety of forms are present in runoff. These are plant nutrients normally present in low concentrations in most surface waters. The addition of feedlot runoff to surface waters often results in the proliferation of undesirable aquatic plants.

Excessive applications of runoff to land, or the continual drainage from manure storage sites can result in a leeching of nitrates through the soil profile, causing groundwater to become contaminated. Nitrate pollution of groundwater has been documented in wells near manure storage areas, under feedlots, and from groundwater collected beneath runoff disposal sites (Loehr, 1974). Contamination of groundwater is particularly serious as little can be done to restore the quality of the resource once it is contaminated. Nitrates have adverse health impacts on humans as well as ruminants, and exposure can be from forages or vegetables which have accumulated nitrates in their tissues, as well as from contaminated drinking water.

Most feedlot rations contain common salt in varying concentrations. Much of this salt ends up on the feedlot surface in the form of manure and urine, and significant amounts of salt can be present in feedlot runoff. In arid regions, storage of runoff and subsequent evaporation can concentrate dissolved salts to a level where application of undilluted runoff can have serious effects on soil fertility. In such areas, the salt concentration may be the limiting factor in determining application rates (Sweeten, 1976). This can also be a problem in humid regions if the ration cattle are fed is high in salt, but in most cases rainfall is sufficient to leech the salts out of the root zone.

Cattle can harbor a number of different microorganisms capable of causing diseases in humans, and feedlot runoff is often contaminated with some of these organisms. The danger to public health in most cases has been minimal. When runoff is applied to land, most disease organisms present in runoff cannot compete with the native soil microflora and are removed naturally within the top 12 inches of the soil profile. Recently, attention has been drawn to the fact that the use of sprinkler irrigation equipment to dispose of runoff can result in the suspension of potentially disease causing organisms in tiny airborne droplets of water. This could be a problem if waste disposal is occurring near human habitation, but as yet the problem is poorly documented.

Feedlots, accumulated feedlot runoff, and waste disposal sites are the source of several pollutants which do not have a tangible impact on public health or water quality, but increasing attention is being attracted to them. Included in this category are dust, odor, and insects, all which can be controlled to a certain extent by good waste management practices.

Runoff Control Technology

The problems of reducing and controlling pollution from cattle feedlots is considerably different than those associated with domestic sewage and industrial pollution. Most domestic pollution occurs at a fairly constant rate, and for the most part is more dilute than feedlot runoff. Pollution resulting from feedlot runoff is usually an event that occurs only intermittently, but the discharge is usually quite concentrated. The total amount of waste generated by cattle feedlots in the U.S. is enormous, but cannot be compared to amounts produced by non-agricultural sources as most of the waste remains on the feedlot surface and never enters any surface waters.

The potential impact of runoff pollution is highly site specific. Considerable variation in the severity of pollution events can be caused by differences in local topography, weather, cover crops on disposal lands, timing of waste disposal, general cultivation practices, and feedlot waste management practices. The absence of an 'average' situation has made the formulation of general design and management criteria difficult. Description of any general criteria for effective feedlot pollution control must be the result of an approach that integrates the selection of the feedlot site, lot management practices, solid waste management, runoff management, and the policy toward eventual disposal of the runoff.

Problems have arisen in trying to upgrade the runoff control facilities at many existing lots, due to the fact feedlots were often located on sites which took advantage of the local drainage and flushing action of surface waters to carry away accumulated waste (Loehr, 1974). The results of these attempts have been consistent with the concept that control of most types of pollution, industrial or agricultural, is often achieved more economically by "in plant" measures of control rather than "end of pipe" treatment (Kneese and Shultze, 1975).

The techniques used to control runoff from open beef feedlots are quite straightforward: extraneous storm runoff is prevented from entering the feedlot surface, and runoff from the feedlot is intercepted upon leaving the feedlot surface and routed to some storage facility. It is then stored until it can be disposed of in some fashion, final disposal being almost always on land.

The types of structures used for clean water diversion, runoff collection, and runoff storage are relatively uniform from one feedlot to the next. Clean water diversion is usually achieved by the construction of a dike or ditch around the portion of the feedlot where extraneous runoff can enter. Runoff collection and interception structures usually consist of a series of drainage channels which collect the runoff and carry it off the feedlot surface and into some type of ditch or collecting terrace. Most feedlots have made provision for the removal of water from the feedlot surface; standing water or muddy conditions on the feedlot surface are not conducive to good cattle performance and also tend to cause odor problems.

Most runoff control systems have some structure to remove some of the solids from the collected runoff prior to its entry into a holding pond. A number of techniques have been used to separate the solid portion of the runoff from the liquid; these include broad shallow basins, porous dams which trap solids, screen dams and various other methods. These are used in almost all cases for two reasons: (1) removal of most of the solids present in runoff prevents excessive loading of the storage pond with organic matter which can cause odor problems as well as increasing the frequency of required dredging of the pond, and (2) successful use of conventional irrigation equipment to dispose of the runoff requires a reduction in the solids normally present in runoff.

Storage structures are usually earthen ponds. Depending on the design, the ponds perform a certain amount of treatment on the runoff through the biological activity of algae and bacteria, and settling of suspended solids. Storage times that are common in most feedlot runoff control systems usually result in considerable reductions in the concentrations of nitrogen, phosphorus, and organic matter.

The use of conventional sewage treatment methods on feedlot runoff has not usually been required as there has been sufficient land to serve as the disposal site. The quality of the water leaving land disposal sites has been found usually to equal the quality achieved by high level treatment processes. Disposal can follow one of two distinctly different approaches, nutrient utilization or "strict" waste disposal.

The nutrient utilization approach limits application of runoff to levels that provide nutrients contained in runoff only in amounts that crops can utilize. Limiting application of wastes to this level conserves the capacity of the soil to treat wastes effectively, as well as the ability of the disposal site to support crop production on a continuing basis.

A "strict" waste disposal policy is based on the goal of disposal of waste as expeditiously as possible, usually onto the smallest land area possible. Application rates are determined with regard to only the amount of waste that can be applied without causing surface or groundwater pollution. A strict disposal approach may be the least cost system in the short run, but this practice cannot be carried out indefinitely on the same disposal site. Application of waste at levels which provide nutrients in excess of the capacity of the plants and soil microorganisms to utilize them can have a number of adverse effects. Nitrate pollution of groundwater, reductions in water infiltration rate, decreased treatment capacity, increased odor and insect problems, and reduced fertility from salt accumulation are among the problems that have accompanied excessive application of feedlot runoff.

The selection of an acceptable application rate must take into account the concentration of nutrients and other chemicals in the effluent, soil characteristics of the disposal site, crops being grown on the site, cultural practices, and general weather conditions. Specification of general effluent application rates applicable to a wide range of locations is difficult due to the extreme variability in the factors listed above. Nitrogen and salt (NaCl) application rates have been used to calculate yearly waste disposal application rates.

While the components of the runoff control systems already described are fairly uniform from one location to the next, the selection of a disposal system allows considerable flexibility. A variety of irrigation systems, including both surface spreading and sprinkler systems, are capable of distributing liquid waste to cropland. Table 2 summarized the characteristics of a number of systems that have been used to dispose of feedlot runoff.

Table 2. Feedlot runoff disposal systems.

	Type of System										
	Tank Wagon	Sprinkler								Gravity	
Factor Considered	Honey Wagon	Hand-Carry Sprinkler	Traveling Gun	Towline	Manure Gun	Solid Set	Side Roll	Boom	Center Pivot	Gated Pipe	Open Ditch
Soil Type	Suitable for use on soils with a wide range of intake rates								Moderate to high intake soils	Soils with moderate to low intake rates	
Surface Topography	Adaptable to a wide range of surface topography						Limited to moderately undulating topography		Wide range	Limited to moderate to flat slopes	
Labor Required	Very High on large operations	High	Low	Moderately low	High on large operations	Very low	Moderate		Very low	High	Very high
Management required 1)	Low	Moderately Low			Moderately Low					High	Very high
Flexibility for Expansion	Inflexible 3)	Moderate	Inflexible 3)	Moderate		Inflexible 3)	Moderate	Inflexible 3)	Inflexible 3)	Very flexible	
Initial Investment	Low to Moderate		Moderate	Low to Moderate		Highest	Low to Moderate		High	Low to Moderate	Lowest
Operating Costs2)	Moderate to High		High	Moderate to High						Low	
Crop Suitability	All except tall growing crops	All	All with Adaptations				All except tall growing crops	All		All	
Size of Operation	Small to Medium Size		All Sizes		Small to medium size		All Sizes		Large	All sizes; depends on topography	
Type of Effluent	Liquids to semi-liquid slurries	Liquids only	Liquids to semi-liquid slurries	Liquids only	Liquids to semi-liquid slurries		Liquids only		Well filtered liquids	Liquids only	

Note: 1) Management refers to the skill required, or the ability to set the system and go off and leave it.
2) Operating costs are a small factor in selecting a waste disposal system.
3) Of course, another system may be purchased.

III. RELEVANT ECONOMIC THEORY AND RESEARCH METHODOLOGY

Theory of the Firm

The theory of the firm provides a basic framework for economic and technical analysis of the production activities of individual agents in the economy. Economic analysis of the firm focuses primarily on factor-product relationships, factor-factor relationships, product-product relationship, and the general conditions under which firms maximize profits. The competitive relationships of various firm sizes are also treated by the theory of the firm.

A firm's production function is a purely technical relation specifying the maximum output obtainable from any given combination of inputs. With the production function, $Y = f(x_1, x_2, \ldots, x_n)$, where x_i are inputs and Y is the maximum output attainable from those inputs, the marginal product of any input x_i is defined:

$$MPx_i = \frac{\partial Y}{\partial x_i}$$

This represents the additional output of Y realized by the addition of the last increment of x_i. For any process where at least one input is held constant, the marginal productivity of additional levels of other variable inputs will eventually decline; the law of eventually declining marginal productivities is nearly universal (Henderson and Quandt, 1975).

The firm's profit equation is defined:

$$\pi = \text{Total Revenue} - \text{Total Cost}$$

$$\pi = Y(pY) - \Sigma p_i x_i - FC$$

where:

pY = selling price of Y

p_i = the price of the ith input

x_i = units of the ith input used

FC = Fixed Cost

For the firm unconstrained to a budget or output level and operating in a perfect market, the theory of the firm specifies the profit maximizing conditions in terms of inputs such that $\partial\pi/\partial x_i = 0$ for all x_i. Rewriting the profit equation:

$$\pi = pY(f(x_1, x_2, \ldots, x_n)) - \Sigma p_i x_i - FC$$

The profit maximizing conditions are then stated:

$$\frac{\partial \pi}{\partial x_i} = pYf_i - p_i = 0$$

$$pYf_i = p_i$$

The quantity pYf_i is the marginal product of x_i times the selling price of Y. It represents the additional revenue derived from adding the last increment of x_i and is defined as the marginal revenue product associated with that addition of x_i. Thus profit is maximized when the marginal revenue product associated with adding one unit of x_i is the marginal factor cost of adding that unit, the marginal cost of adding one unit of x_i being equal to the selling price per unit of x_i.

A given level of output can be obtained by a variety of input combinations. For the two input production function, $Y = f(x_1, x_2)$, constrained to producing a constant level of output, Y_0, any change in x_1 and x_2 must have a total differential of Y equal to zero. For the two-input case:

$$dY = \frac{\partial Y}{\partial x_1} dx_1 + \frac{\partial Y}{\partial x_2} dx_2 = 0 \tag{1}$$

The rate at which x_1 must substitute for x_2 (to yield a total differential of zero) is referred to as the marginal rate of technical substitution and is defined mathematically: $MRTS = -dx_1/dx_2$. Rearranging equation 1,

$$dx_1 \frac{\partial Y}{\partial x_1} = - \frac{\partial Y}{\partial x_2} dx_2$$

$$\frac{MPx_1}{MPx_2} = -\frac{dx_2}{dx_1}$$

Thus at any combination of x_1 and x_2 yielding Y_0, changing x_1 and x_2 with Y_0 remaining constant necessitates substituting x_1 for x_2 in the inverse ratio of their marginal products.

For the firm producing a given output, Y_0, the profit equation is expressed:

$$\pi = \text{Total Revenue} - \text{Total Cost}$$

$$\pi = Y_0(pY) - \Sigma p_i x_i - FC$$

and profit maximization is achieved by minimizing total cost. The theory of the firm specifies the profit maximizing conditions for constrained cost minimization in terms of the LaGrange multiplier

$$L = \Sigma p_i x_i + FC + \lambda(Y_0 - f(x))$$

(where λ is an undetermined LaGrange multiplier). Cost is minimized when

$$\frac{\partial L}{\partial x_i} = \frac{\partial L}{\partial \lambda} = 0$$

For the two input case, $Y_0 = f(x_1, x_2)$, the LaGrange multiplier is written

$$L = x_1p_1 + x_2p_2 + FC + \lambda[Y_0 - f(x_1, x_2)]$$

and profit maximizing (cost minimizing) conditions are specified in terms of the following partial derivatives:

$$\frac{\partial L}{\partial x_1} = p_1 + \lambda f_1 = 0$$

$$\frac{\partial L}{\partial x_2} = p_2 + \lambda f_2 = 0$$

$$\frac{\partial L}{\partial \lambda} = Y_0 - f(x_1, x_2) = 0$$

where:

$f_1 = \partial Y / \partial x_1$

$f_2 = \partial Y / \partial x_2$ for $Y = f(x_1, x_2)$

Solving by the method of simultaneous equations yields the basic constrained cost minimization profit maximizing conditions:

$$\frac{p_1}{p_2} = \frac{f_2}{f_1} \quad \text{or} \quad \frac{p_1}{p_2} = \frac{MP_2}{MP_1}$$

or

$$MRTS = \frac{p_1}{p_2}$$

Thus profit is maximized when inputs are combined such that the marginal rate of technical substitution (the rate inputs can be substituted technically) is equal to the input price ratio--the rate at which the inputs can be substituted in the marketplace.

From the production function and the use of the profit maximizing conditions, the total cost associated with a number of different output levels can be generated. From this data can be derived a cost function which describes the total cost as a function of output. Dividing the total cost of producing any level of output, Y_0, by the output Y_0, yields the average cost at that point.

Thus far, the concept of time has not been addressed, however, the firm and its production function can be defined with respect to time. Firm size is measured as output per unit time, and quantities of output and inputs are measured as flow rates per unit time. The production function itself is defined for the time period which is short enough that: 1) no fixed inputs can be changed, and 2) the production relationships are not altered by technological change. This time period is also referred to as the "short run". In the long run, the first constraint is relaxed and all inputs are considered to be variable.

As defined, the short run is the time in which a firm cannot change the level of its fixed inputs. Due to the fact of declining marginal productivities, this places an absolute maximum on the output any firm can produce in the short run. Corresponding to its production function, each firm will have its own short run cost function describing the cost of producing the range of output levels its fixed inputs will allow. Figure 1 presents a series of hypothetical short run average cost curves for a variety of firm sizes. Relaxing the constraint of fixed inputs, a long run average cost curve is generated and is defined as the envelope of all the short run average cost curves, tangent to all but intersecting none (Heady, 1952). Consistent with the assumptions of maximum technical efficiency in the production function and minimum cost of producing a given output by the cost function, the long run average cost curve represents the minimum unit cost of producing any level of output for the entire group of firms.

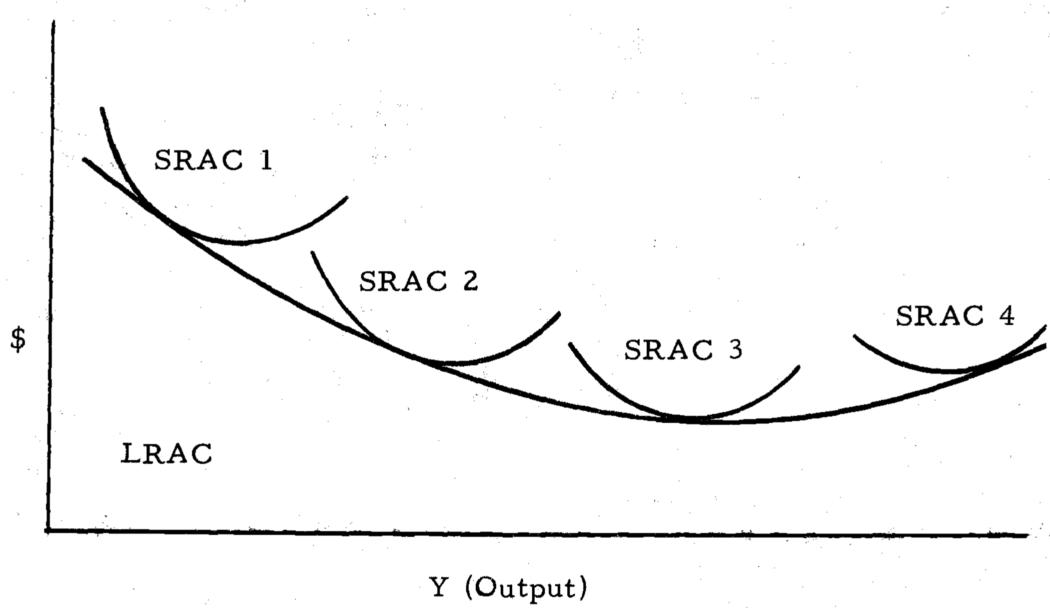

Figure 1. Hypothetical short run and long run average cost curves.

The existence of economies and diseconomies of size will be apparent from the shape of the long run average cost curve. The long run average cost curve presented in Figure 1, with regions of decreasing and increasing costs is believed to be typical of most production activities in the American economy (Ferguson and Gould, 1975).

Application of Economic Theory to the Problem of Runoff Control

Use of the optimizing conditions presented in the traditional theory of the firm poses some problems when applied to the case of controlling cattle feedlot runoff. The standard profit maximizing rule of equating marginal cost with marginal revenue assumes the product, Y, is sold for a positive price. In the case of feedlot runoff control, the "product" is the prevention of runoff from the feedlot; the "price" this control "sells" for is the avoidance of fines and jail sentences that would be imposed if the runoff was not controlled. Thus, there is no revenue in the normal sense, only costs.

For a profit maximizing firm, constrained by law to achieve a certain level of control, the problem resolves to the selection of the least cost system. This problem is exactly analogous to the case presented describing the behavior of a firm maximizing profits (minimizing costs) subject to producing a given output, if the firm is deal-in a perfect market.

The application of the profit maximizing conditions of economic theory presents an additional problem of the inherent assumption of continuous data in economic theory. With respect to feedlot runoff, production (control) is achieved by some combination of runoff storage volume and irrigation capacity. These two imputs can substitute for each other continuously. However, this is the extent of the continuous data in this case.

With respect to the disposal system, a variety of irrigation systems are available, which for the most part substitute some technological feature (capital) for labor. Within each system, the technical constraints or time limitations restrict substitution of labor for capital to a number of discrete combinations.

In addition to different combinations of labor and equipment required to achieve a given level of control using a given management scheme and irrigation system, other substitutions are possible using different systems and management alternatives. For any given site and feedlot size, combining five management alternatives, five pumping rates and four irrigation systems yields a potential 100 different combinations of inputs capable of meeting the desired level of control. Thus, the data developed will not be continuous, but the wide range of technical and managerial options in the data present a near continuous spectrum of imput combinations. These points will be represented by a series of budgets representing the annualized cost of owning and operating the given system. In this case the cost functions necessary for applying the traditional optimizing calculus will not be estimated. The least cost system was identified by calculating several discrete combinations of management policy, pump rates, irrigation systems, etc., and selecting from those the least cost system.

Research Methods

In the previous sections, production functions, cost functions, and optimizing conditions were discussed under the assumption that the production function was continuous. The production and cost functions, however, are simply explicit functions that express output and cost as a function of input levels and output, respectively. They may describe a continuous set of points, a finite group of points, or a single point. What this study seeks to derive are the cost functions that describe the cost of feedlot runoff control for one level of control, at different locations, and for different management policies. The next section will review the research methods that have been used to describe cost functions, identifying the advantages and problems associated with each.

Statistical Estimation

Estimation of cost functions by statistical methods is common to economic analysis (Haynes and Henery, 1974). Such studies normally utilize historical cost and production data from cross-sectional studies of a particular industry, and analysis is by means of multiple regression analysis. Significant problems exist with respect to stratifying the industry into sub-groups merely on the basis of plant size. Any cross-sectional study of firms probably finds many of them in some form of maladjustment, i.e., some are producing less output at given cost than specified by the firm's cost function (Erdman, 1944).

Problems also exist with respect to the quality of the data used in the regression analysis. Such data is necessarily given at the discretion of the firm owner, and thus may be incomplete or biased by a firm's accounting system. In cases such as the one this study is addressing--the costs of some production process imposed on firms by government order--surveys may elicit "strategic" responses overstating the costs in order that the study produce results favorable to the collective desire of the industry to avoid the activity required.

The essential nature of the least-squares method of fitting a line to a series of points insures that the curve that is fitted will not be the lowest possible. The cost functions derived by least-squares analysis of a cross-section of firms are not consistent with the assumptions of economic theory--that the cost function represents the minimum cost of producing each and every level of output. Perhaps even more serious is the fact that the statistical treatment of the data may result in considerable variation in the type of cost curves described. The study of feed mills by Stoltsheimer, Bressler, and Boles (1961) showed that selection of the equation form used in the regression analysis can have a great deal of effect on the conclusions to be drawn from the same data. Their study examining the effects of using different equation forms yielded radically different cost curves, which were all of equivalent validity based on their respective r^2 values.

For the cost functions this study is trying to derive, no data base exists as the response of feedlot firms to the federal regulations has not occurred. This is partly due to the fact that until recently, considerable confusion existed as to the interpretation of the regulation, and perhaps even more existed as to the design criteria that would insure compliance with the law.

Survivorship Approach

As an alternative to trying to estimate cost functions by the statistical method, Stigler (1958) proposed the survivorship method. Instead of trying to estimate an actual cost function, firms are classified by size and examined to determine which groups are gaining/ losing in market share. These changes were assumed to be indicative of the long run cost relationships in the industry.

There are a number of immediate objections to the use of this technique to estimate industry trends with respect to costs as a function of firm size. Since this technique makes no claim to measure costs, a question can be raised: just what is it measuring? One of the advantages of firm size (in addition to the potential to take advantage of volume discounts on purchased inputs) is increased market power and market intelligence. For firms in the agricultural sector, which normally face price swings of considerably larger magnitude than experienced in the rest of the private sector, increased marketing skill may result in the more visible success of large, more sophisticated and knowledgable firms. This may occur despite the fact that for the most part, the majority of the firms have cost functions that are very similar.

Regional differences arising from areas having an absolute advantage in the production of a certain agricultural product may also confuse the analysis via survivorship.

Synthetic Method

The synthetic or engineering method derives cost functions by either a total or partial synthesis of costs. The production process is broken into various stages, and using existing production technology tempered with engineering knowledge, least cost solutions are calculated for the various subprocesses. This method has the advantage of stabilizing technology between all the firm sizes, and can be used with expected future prices to be a predictive model. However, it is a time consuming and expensive method.

Bressler (1945) has raised the valid objection that potentially increasing variable costs are ignored and that some costs will always be overlooked, resulting in a cost value that is conservative. He also has noted that this method assumes constant marginal productivities for all inputs, and this does not account for differences in the quality of various inputs, especially labor and management.

Due to the fact that the data base does not exist for either of the two previous methods, the synthetic method was used. A computerized cost estimating model was developed to calculate the costs of feedlot runoff. A total synthesis of costs was required, as the various design parameters vary considerably from one site to another. A description of the model is contained in the following chapter.

IV. COST ESTIMATING MODEL

Function of Model

The basic function of the model is to calculate initial investment and annual operating costs for feedlot runoff control facilities. The model is comprised of a set of engineering cost equations reflecting assumptions about the design of various control system components. Initially, the model was designed to provide cost information on runoff control facilities for one, ten, and 100 acre feedlots, (representing animal populations of 200, 2000, and 20,000 head respectively), but will work for any size feedlot.

The model will provide investment and operating cost information on a standardized runoff control system designed to control runoff from open air, earth surfaced lots. As described in Chapter II, a variety of systems are available to control runoff from feedlots. All runoff control systems are assumed to have the following basic components:

1. Some type of diversion structure to prevent clean water from entering the feedlot;
2. A structure to collect and intercept runoff from the feedlot;
3. A settling basin of some type to remove suspended solids from runoff;

4. A retention pond to store accumulated runoff until it evaporates or can be disposed of without entering surface waters; and,
5. A disposal system, commonly some type of irrigation equipment, to pump out the retention pond and dispose of the accumulated runoff onto land.

Regardless of feedlot size or location, items 1-4 are assumed to be constructed according to basic design assumptions described in the latter part of this chapter. For the purpose of cost comparison, four of the irrigation systems listed in Table 2, hand move, side roll, stationary big gun, and traveling big gun were chosen for analysis as potential disposal systems. The hand move and big gun systems were budgeted at each location, regardless of feedlot size or pumping requirements. The travelling big gun system was budgeted subject to a minimum pumping rate. The side roll system was budgeted subject to a minimum disposal plot area. These were selected to represent the sprinkler irrigation systems most commonly used to distribute liquid waste.

Model Inputs

The cost estimating model requires both design inputs and cost inputs. The design inputs were developed independently of the author by Professors J.R. Miner and R.B. Wensink, Department of

Agricultural Engineering, Oregon State University. The cost inputs were developed by the author.

Design Inputs

The basic design parameters required to calculate the initial investment for a feedlot runoff control system are: 1) feedlot area, 2) a design pumping rate (volume per day), 3) a required storage volume, and 4) the land area required for disposal of accumulated runoff. The storage volume required is a function of the pumping rate, management policy with respect to frequency of pumping, and climatic inputs. Land area required for disposal is primarily dependent on the management policy with respect to nutrient application rates. To calculate the annual operating costs, one additional variable is required, the average number of days pumped per year.

The design pumping rates, storage volumes, and pumping days per year were provided by the Feedlot Runoff Design Program developed by Wensink and Miner (1977). Storage volumes and pumping days per year (for given pumping rates) required for compliance with the 1983 EPA guidelines were estimated for seven U. S. locations. Historic weather data was used for the climatic inputs for the Feedlot Runoff Design Program. Table 3 lists the seven locations and associated climatic attributes. These values were calculated for seven management alternatives, and all design parameters were calculated

Table 3. Climatic attributes of selected feedlot locations.

Location	Average Annual Rainfall (cm)	Average January Temp (°C)	25 yr-24 hr Rainfall (cm)	Years Cumulative Data	Calculated Av. Annual Feedlot Runoff[a] (cm)
Pendleton, OR	34.01	-0.6	3.8	1914-1971	4.06
Lubbock, TX	47.29	3.9	12.7	1914-1972	15.21
Bozeman, MT	48.84	-7.2	6.9	1908-1970	12.09
Ames, IA	78.51	-6.7	13.7	19-1-1970	28.06
Corvallis, OR	100.74	3.3	11.4	1914-1971	31.80
Experiment, GA	126.75	8.9	17.0	1926-1970	49.27
Astoria, OR	191.49	4.4	14.0	1914-1971	83.69

[a]From SCS equation (Wensink and Miner, 1975).

on a per feedlot-acre basis and can be extrapolated to any size feedlot. Table 4 contains the descriptions of the seven management policies. All design management alternatives model some irrigation schecule suitable for producing livestock feed, either grain or forage. Sufficient variability exists within the seven alternatives to allow some of them to simulate the irrigation schedules required for other types of crops.

Land areas required for disposal were calculated for two disposal policies: 1) nutrient utilization, and 2) strict disposal. For each policy, two land areas were calculated: 1) the land area required to accept one day's pumping (termed the disposal plot), and 2) the total land area required to accept the total year's pumping (called the disposal site).

The disposal plot area was calculated on the basis of the design pumping rate (volume/day) and a maximum daily application rate. Initially a maximum daily application of two acre-inches per acre was assumed. The disposal plot area (in acres) was then calculated:

Disposal Plot Area = design pumping rate/2, with design pumping rate expressed in acre-inches/day.

The disposal site area was calculated on the basis of a maximum yearly application rate of nitrogen. Using the average volume pumped

Table 4. Physical interpretation of the seven runoff management dewatering alternatives.

Policy	Situation Simulation	Dates Runoff Disposal Permitted
1	All year disposal	All year[a]
2	Apply effluent to corn crop plus pre-planting (April) disposal	April, June, July, August
3	Apply effluent to corn crop plus after harvest (Oct 15-Nov 15) disposal and pre-planting (April) disposal	April, June, July, August, Oct 15-Nov 15
4	Apply effluent to corn crop	June, July, August
5	Apply effluent to corn crop plus post-harvest (Oct 15-Nov 15)	June, July, August, Oct 15-Nov 15
6	Apply effluent to hay crop and winter months disposal	Jan 1-May 15; June 15-30; July 15-31; Aug 15-31; Sep 15-30; Oct 15-Jan 1
7	Apply effluent to hay crop	Apr 1-May 15; June 15-30; Jul 15-31; Aug 15-31; Sep 15-30; Oct 15-31
1f	All year disposal	All year[b]

[a]Requires at least a full day's pumping volume in the retention pond to pump.
[b]Will pump with less than a full day's pumping volume in the retention pond.

per year (provided by the Feedlot Runoff Design Program) and assuming a nitrogen concentration for the effluent, the total weight of nitrogen applied per year was calculated. Dividing this figure by the applicable yearly application rate gave the disposal site area required. Miner, et al, (1977) determined that over a wide range of conditions, a value of 150 parts per million was a reasonable average for the nitrogen concentration of feedlot runoff lagoon effluent after application via sprinkler irrigation systems. Maximum annual nitrogen applications of 200 lb. /acre and 1200 lb. /acre were established for the nutrient utilization and strict disposal policies, respectively. These values correspond to maximum annual applications of 5.9" and 35.4" per acre for the nutrient utilization and strict waste disposal policies, respectively. These application rates were selected by agricultural engineers experienced in animal waste management to represent reasonable applications of nitrogen under the two disposal policies. They are <u>not</u> application rates specified by the EPA or any other regulatory agency or government body.

An additional constraint of allowing a maximum of seven inches of combined rainfall and irrigated effluent in any seven day period was imposed. In some cases this resulted in a disposal site area in excess of that required by the nitrogen loading.

Cost Inputs

Cost inputs representing various component and service costs were provided by extension specialists in waste management and irrigation, equipment dealers, and various contractors in the Northwest. Most service costs -- excavation, engineering, surveying, etc.--were provided as estimates for the entire U.S. All irrigation component costs are actual market prices for 1977 as quoted by various manufacturers and equipment dealers. Tables 1-7 in Appendix A contain a listing of all cost inputs used in this study.

Program Design

The program was written in standard Fortran IV and run on Oregon State University's OS-3 computer system. Figure 2 illustrates the basic operation of the program. A complete listing of the program is contained in Appendix B.

The cost equations were divided into 2 groups: 1) those used to calculate initial investment, and 2) those used to calculate annual operating costs. The following sections describe the assumptions and procedures used to derive these equations.

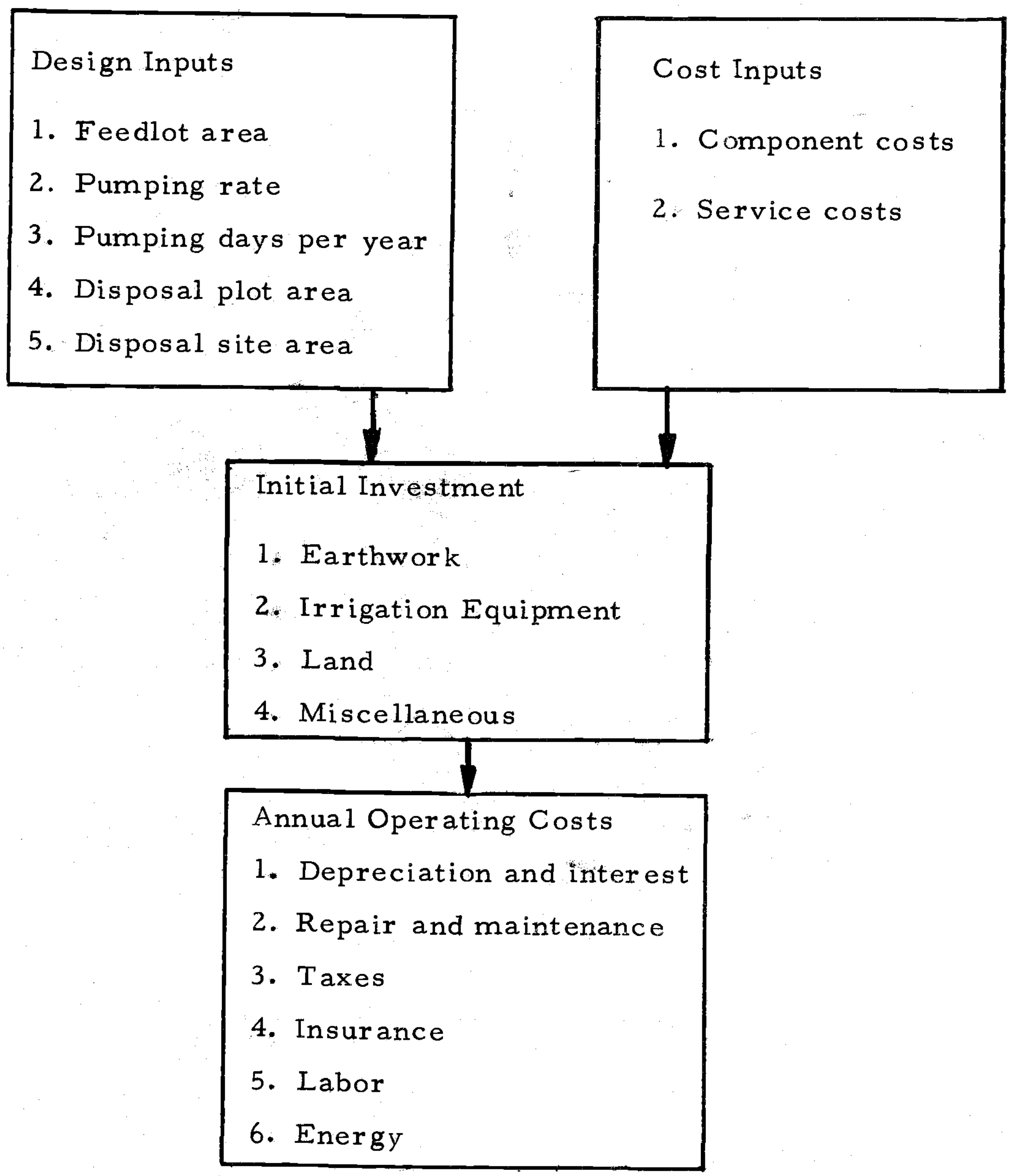

Figure 2. Block diagram of runoff control cost model.

Investment Items

Investment items were grouped into four categories: 1) earthwork, 2) land, 3) irrigation equipment, 4) miscellaneous items.

Earthwork

Retention Pond. The retention pond was assumed to have the following configuration:

1. Water depth is a maximum of 14 feet when the pond is full;
2. One foot of freeboard is provided, making total depth equal to 15 feet;
3. The pond is square, inside slope is 2:1, and outside slope is 3:1; and,
4. The top width of the berm is six feet.

Figure 3 illustrates a cross section of the retention pond.

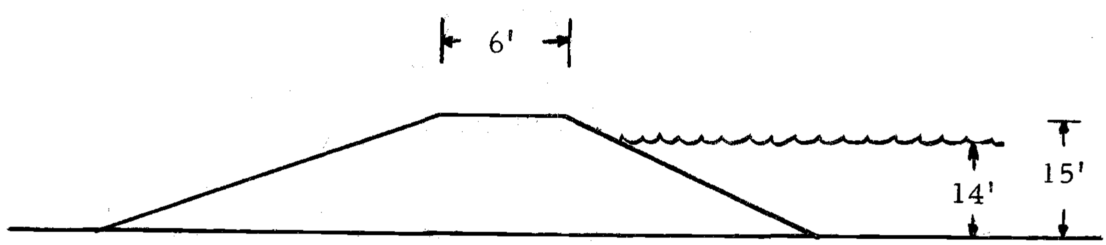

Figure 3. Cross-section of retention pond earthwork.

The required storage volume was given as a program input. However, as described in the design assumptions, one foot of freeboard must be provided. Thus, a volume larger than the given storage volume must be excavated to satisfy these two requirements. The procedure used has three basic steps;

1) Given the required storage volume, the length of the pond at the waterline is calculated;
2) This length is used to calculate the length of the pond at the freeboard level; and,
3) The length of the pond at the freeboard level is used to calculate the required excavation volume.

The volume of such a pond is calculated by the equation,

$$V = w\ell d + sd^2(w+\ell) + 4/3 s^2 d^3 \quad (1)$$

with w, ℓ, d, and s defined as shown in Figure 4.

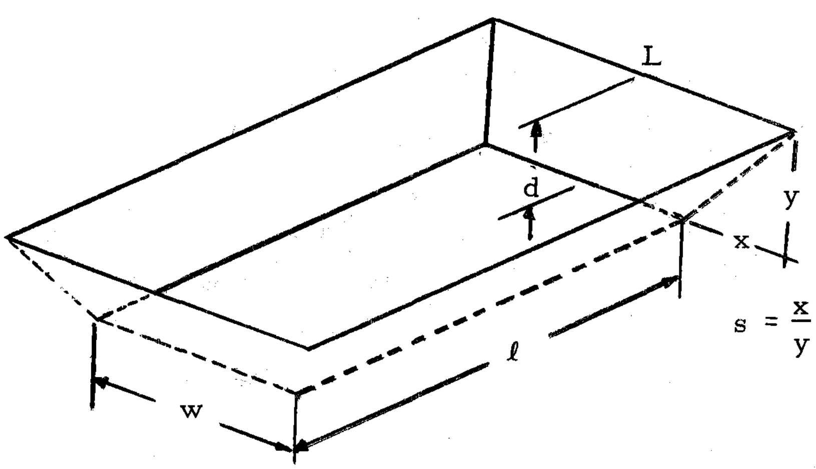

Figure 4. Retention pond configuration (adapted from L.R. Shuyler, et al, 1973).

As provided in the design assumptions, the pond is square, hence width equals length. Substituting w for ℓ, Equation 1 is rewritten

$$V = w^2 d + sd^2(2w) + 4/3s^2d^3 \qquad (2)$$

The length of the pond at the top, L, can be expressed as w + 2ds. Rearranging yields the identity w = L - 2ds. Substituting L = 2ds for w in Equation 2 yields

$$V = (\ell-2ds)^2 d + 2sd^2(L-2ds) + 4/3s^2d^3 \qquad (3)$$

Utilizing Equation 3, with s = 2 and d = 14, as provided in the design assumptions, the required holding volume can be expressed by the equation:

$$HLDVOL = 14(L-56)^2 + 784(L-56) + 14630$$

which simplifies to:

$$HLDVOL = 14L^2 - 784L + 14630 \qquad (4)$$

where:

HLDVOL = volume of pond in $ft.^3$

L = length of pond (at the top)

Given HLDVOL as the required storage volume supplied by the Feedlot Runoff Design Program, Equation 4, rearranged, yields the following quadratic equation:

$$0 = 14L^2 - 784L + 14630 - HLDVOL.$$

The solution of this equation, L, is the length of the retention pond (at the water line) when full. Solving by the quadratic formula,

$$L = 23 \pm \frac{(HLDVOL-3654)^{1/2}}{14}$$

Under the assumption of one foot of freeboard and an inside slope of 2:1, the length of the pond at freeboard level is equal to the length at the water line plus 2ds. Thus, the length of the pond at freeboard level, L_{Fb}, is equal to

$$L_{Fb} = 32 + \frac{(HLDVOL-3654)^{1/2}}{14}$$

Given this length, the volume that must be excavated to contain a given volume, HLDVOL, while providing one foot of freeboard, can be calculated by substituting L_{Fb} into Equation 3. With $s = 2$ and $d = 15$, (total depth), as provided by the design assumptions, the substitution yields

$$EV = [L_{Fb}-2(15)(2)]^2 15 + 2(15)^2(2)[L_{Fb}-2(15)(2)] + 4/3(2)^2(15)^3$$

which simplifies to:

$$EV = 15(L_{Fb}^2-60L_{Fb}+1200)$$

where:

EV = necessary excavation volume in ft.^{3}

L_{Fb} = length of the pond at freeboard level in feet

Dividing by 27 to convert cubic feet to cubic yards:

$$EV = 0.555(L_{Fb}^2-60L_{Fb}+1200)$$

This represents the volume that must be excavated to build a retention pond capable of holding the given HLDVOL and allowing for one foot of freeboard.

Settling Basin. One acre-inch of settling basin volume was assumed for each feedlot acre. Excavation volume was calculated as follows:

$$SBVOL = FLAREA(134.4)$$

where:

SBVOL = Excavation volume in cubic yards

FLAREA = Feedlot area in acres

134.4 = Cubic yards/acre-inch

Clean Water Diversion. Clean water diversion and runoff collecting terraces were assumed to be constructed as one, with the earth excavated for the collecting terrace comprising the clean water diversion dike. Clean water diversion runoff collection terraces were assumed to be eight feet wide and required for three sides of the feedlot. Assuming a square feedlot, the cost of construction for clean water diversion was calculated by the following equation:

$$DCIV = (3)(FLAREA \times 43560)^{1/2}(COST\ B)$$

where:

FLAREA = feedlot area in acres

43560 = square feet per acre

COST B = construction cost per linear foot

The cost of constructing the retention pond and settling basin is total excavation volume times the cost per cubic yard excavated. The sum of this cost and the cost of clean water diversion is the total investment in earthwork. The cost of disposing of excavated materials, either on site or elsewhere, is highly site specific and was not accounted for.

<u>Land Occupied by Structure</u>

A cost was assessed for land occupied by the retention pond, settling basin, collecting diversion structures, and, depending on disposal policy, the disposal site.

<u>Retention Pond</u>. Pond configuration and construction is quite site specific, depending on local topography and other considerations. Some will be excavated simple as a "hole in the ground"; others may require earthern berms, and some may be of other than square dimensions. For purpose of calculating land area required, the following method was used to calculate land area used in a "average" situation: the land area required is square, with dimensions L + 101 feet, calculated by adding to L, (pond length of <u>freeboard level</u>), the sum of 101, comprised of:

1) 6 feet (for top width of berm), plus;
2) 45 feet (horizontal distance covered by 15 foot berm with 3:1 outside slope), plus;
3) 50 feet (25 foot setback for fence at each end of pond).

Thus, the land area required for the retention pond and perimeter, LARPAP, (in acres) was calculated as

$$LARPAP = \frac{L^2+202L+10201}{43560}$$

$$= \frac{(L+101)^2}{43560}$$

where:

L = length of the retention pond at freeboard level

43560 = $ft.^2$/acre

Settling Basin. Settling basins were assumed to have a uniform depth of four feet, a length to width ratio of 2:1, an inside slope of 3:1, and square ends.

The volume of such a basin is calculated by the equation

$$V = L(W-DS)D$$

where:

L = length of basin at top

W = width at top

S = inside slop

D = depth

V = volume

Substituting 2W for L and replacing the variables S and D with the appropriate constants yields the quadratic, $0 = 2W^2 - 24W - V/4$, which given volume in cubic feet, can be used to solve for W. Settling basin dimensions derived by this method were used to calculate land areas required. Dimensions and surface areas of settling basins for one, ten, and 100 acre feedlots are contained in Table 5.

Table 5. Settling basin dimension and surface areas.

Feedlot Acres	Settling Basin Dimensions (feet)	Land Area Occupied (acres)
1	28 x 56	0.036
10	73.5 x 147	0.248
100	219 x 438	2.202

Diversion and Collection Terraces. Using design assumptions previously described, the land area occupied by the diversion and runoff collecting terraces was calculated as follows:

$$\text{LADIV} = \frac{8 \times 3\sqrt{\text{FLAREA} \times 43560}}{43560}$$

where:

LADIV = area in acres required for clean water diversion

$3(\sqrt{\text{FLAREA} \times 43560})$ = linear feet of diversion required

8 = width of diversion

43560 = ft.^2/acre

Disposal Site. Under a nutrient utilization disposal policy, land was assumed to be utilized primarily for crop production, and was not included as a cost. With a strict disposal policy, the disposal site was assumed to be rendered unfit for crop production and becomes part of the required investment.

Total land cost is the total land area required for the retention pond, settling basin, collecting/diversion terraces and disposal, (if applicable), times a per acre cost of land.

Irrigation Systems

The cost of any irrigation system was computed in two parts:

1. The cost of the system capable of achieving one day's pumping; and,
2. The cost of extending the system to cover the entire disposal site.

Each irrigation system consists of three basic components; 1) piping, 2) pump(s), and 3) some type of sprinkling unit. The core of the system was the pump, piping, and sprinklers necessary to apply MAXDA of waste to the disposal plot. The cost of extending the system was that of additional mainline required to facilitate irrigating the total disposal site area with the basic system. Implicit in this procedure was the assumption that the same volume is pumped each day pumping occurs.

Sprinkler Units. Hand move: The basic assumptions used in designing a hand move waste disposal system are outlined below:

1. The laterals are comprised of 40' sections of 3" or 4" aluminum pipe with a sprinkler on each 40 section;
2. Laterals are moved 60 feet along the mainline to the next set (sprinkler spacing is 60' x 40');

3. Area irrigated per sprinkler is ≈ .0551 acre;[7/] and,

$$\frac{(60 \cdot 40)}{43560} = .055096 \text{ acre}$$

4. Hourly application rate is 0.33"/hr.

The number of 40' sections that must be purchased to irrigate the disposal plot depends on the duration of a set. It was assumed that two sets per day would be the maximum, regardless of how short the sets were. If the disposal plot is irrigated with two sets per day, and a minimum of two hours is allowed to move lateral to next set, a maximum of 10 hours per set is allowable. Thus, with

TSET $\leq$ 10 hours, the disposal plot can be irrigated in two sets; if

TSET > 10 hours, the disposal plot must be irrigated with one set.

Hours required per set, TSET, is dependent on MAXDA. With MAXDA expressed in acre-in./acre-day, and an hourly application rate of 0.33 acre inches;

$$\text{TSET} = \text{MAXDA}/0.33$$

With irrigated area per sprinkler equal to 0.0551 acres, the number of sprinklers required to cover a 1 acre set equals

$$\frac{1}{0.0551} = 18.15$$

[7/] Sprinkler spacing is 60' x 40': 60' x 40'/(43,560 ft.^{2}/acre) = 0.0551 acres.

Given the cost per 40 foot section, COST D, the cost per acre/set equals 18.15 times COST D. The total cost of laterals required to irrigate a given disposal plot, ADP, was calculated by one of the following equations:

(1a)* IRCA = 18.15 (COST D)(ADP)

(1b)** IRCB = 9.075 (COST D)(ADP)

* TSET > 10 hours; ADP irrigated in 1 set/day.

** TSET $\leq$ 10 hours; ADP irrigated in 2 sets/day

Side roll: Design assumptions for the side roll system were identical to those for the hand move system, with two additions:

1. Laterals are mounted on 72 inch wheels; and,
2. A small gasoline powered drive unit is used to advance laterals to the next set.

A 1320 foot lateral covers 1.8 acres per set, therefore, the cost per set-acre equals

$$\frac{\text{COST E}}{1.8} = 0.556 \text{ COST E}$$

where COST E is the cost of a 1320 foot lateral complete with wheels, sprinklers, and drive unit.

The total cost of laterals for the side roll system was calculated with one of the following equations:

(2a)* IRCC = 0.556 (COST E)(ADP)

(2b)** IRCD = 0.278 (COST E)(ADP)

* TSET > 10 hours; ADP irrigated in 1 set

** TSET < 10 hours; ADP irrigated in 2 sets

Stationary big gun: Assuming an operating pressure of 100 psi, 11 discrete sizes (GPM) are available from a major manufacturer. Table 8 (Appendix A) lists discharge rates and areas irrigated per set, and application rates for these. In actual practice, a continuum of set sizes may be achieved by manipulating operating pressure and nozzle size.[8/] The cost of a big gun system was calculated on the assumption that the operator, by minor modifications, can obtain a system (with one or more big guns) that will irrigate an area equal to ADP. Hence, the basic design variable for the big gun system is the gpm discharge required, not the size of the disposal plot.

The big gun(s) required for a given system were selected on the basis of total system discharge (gal/min) as calculated in the following section describing pump selection. Given a required discharge gpm, the guns were selected and the cost calculated using the following assumptions:

1. The average application rate in 0.33/hr. for all big guns (actual rates vary from 0.20 to 0.50 acre-in/hr.);

8/ For details see product data, Nelson Irrigation Co.

2. The allowable sets per day and hours per set are the same as described for the hand move and side roll systems;
3. 1000 gallons per minutes is the maximum discharge rate of a single big gun; and,
4. All systems requiring a discharge rate of less than 1000 gpm will use one big gun.

When the required discharge rate is greater than 1000 gpm, more than one gun will be necessary. In such cases, the minimum number of guns possible were assumed to be used, and all were assumed to have an identical discharge rate. For example, with a required discharge rate of 2400 gpm, 3 guns are necessary and the discharge rate of each would be 800 gpm. The total cost of the big gun(s) was based on the number of guns and their individual discharge capacity. The cost information on big guns is contained in Table 1 of Appendix A.

Traveling big gun: The traveling big gun under consideration was assumed to be equipped with a big gun type sprinkler whose characteristics are identical to the stationary big gun already described. Models are available with discharge capacities of ~ 250 to 1000 gpm.

From Table 8 of Appendix A, it is seen that application rates while stationary are fairly constant; application rates while the unit is in motion is primarily a function of travel speed. Using an average stationary application rate of 0.33 ac.-in./hr., moving big gun systems were budgeted using the following assumptions:

1. The moving big gun is capable of varying travel speed to apply from 1 to 6 inches of waste per-acre/day;
2. Two hours each day are allowed for moving the unit to next set, hence 22 hours/day are allotted for pumping;
3. Units are available with capacity of 250-1000 gpm;
4. If more than one unit is required, all will have identical capacity; and,
5. The system is not applicable when required pumping rate is less than 250 gpm (22 hr pumping day).

With DPRATE, (design pump rate) in acre-inches/day, the required discharge capacity (gpm) equals

$$\text{MBGGPM} = \frac{\text{DPRATE} \times 27153}{22 \times 60} = 20.57\ \text{DPRATE}.$$

where:

27153 = gal. per acre-inch

22 = pumping hours per day

60 = min./hr.

As stated in the design assumptions, the maximum capacity is 1000 gpm; where MBGGPM is greater than 1000, the number of units required is equal to NMBG, calculated by the FORTRAN equation[9/]

NMBG = IFIX(MBGGPM/1000 + 1.0)

The capacity of each unit is equal to MBGGPM/NMBG.

The total cost of moving big gun units is NMBG times the price per unit listed in Table 1 of Appendix A. A cost breakdown of the component costs of a traveling big gun is contained in Table 2 of Appendix A. Table 3 of Appendix A displays the discounting technique that was used to derive the cost listed in Table 1 of Appendix A.

Pumps. All systems were assumed to use electrically powered centrifugal pumps. The hand move and side roll systems operate at 50 psi, the big gun and moving big gun systems at 100 psi. Pumps are selected primarily on the basis of two criteria; total dynamic head and gpm discharge. Total dynamic head is a measure of the combined resistance of pipe friction, operating pressure and any lift of the water.

Under the assumptions of a level field, no lift to the pump, 20% loss of pressure due to mainline friction and couplings, etc., total

---

[9/] The fortran command IFIX simply truncates the value that is contained in the parentheses following the command. The addition of 1 to MBGPM/1000 insures that any decimal value will be rounded to the next highest integer.

dynamic head, in feet, was calculated as follows:

$$\text{FEET OF HEAD} = 2.31\,(\text{operating pressure} + \text{pressure losses in system})^*$$

$$= 2.31\,[(1.2\,(\text{operating pressure})]$$

*expressed in pounds per square inch

The discharge capacity (gpm) required for a given system was based on the design assumptions previously listed for each type of system. Pump discharge required for any hand move, side roll or big gun is dependent on coverage of ADP with one or two sets. With the disposal plot irrigated in one set, the discharge capacity (gpm) required was calculated as follows:

$$\text{GPM} = \frac{\text{DPRATE}\ (27153)}{\text{TSET}\ (60)} = \frac{452.5\ (\text{DPRATE})}{\text{TSET}}$$

where:

1) DPRATE = design pumping rate (acre-inches/day)
2) 27153 = gal. /acre-inches
3) TSET = hours per set
4) 60 = minutes/hour

With ADP irrigated with two sets, GPM was calculated as follows:

$$\text{GPM} = \frac{\text{DPRATE}\ (27153)}{2(60)\ \text{TSET}} = \frac{226.3\ \text{DPRATE}}{\text{TSET}}$$

The discharge capacity required for a traveling big gun system was calculated using the procedure previously described. Costs of various size pumps are presented in Tables 4 and 5 of Appendix A (assuming pumping heads of 138 feet and 277 feet respectively). These costs include the pump, motor, all electrical switches, control panel, pump base, and installation. The cost of all accessories to the basic pump-motor combination was estimated at 100% of the pump-motor cost. Table 6 in Appendix A contains an itemization of these costs for 2 different pump sizes. The procedure used to determine the pump cost for a given system is outlined below:

1. Pump costs for hand move and side roll systems are taken from Table 4 of Appendix A. Pump costs for big gun and moving big gun systems are taken from Table 5 of Appendix A.
2. In each case, the smallest size pump which has capacity greater than or equal to required gpm for the system in question is selected.
3. When the required discharge rate cannot be achieved by the use of one pump, multiple pumps (of identical size) will be selected. In each case the smallest number of pumps possible will be used.
4. The total pump cost is the product of the number of pumps required and the price of that pump(s).

Mainline. All systems were assumed to utilize portable aluminum mainline. The total cost was determined by pipe diameter and length. Table 7 of Appendix A presents maximum (in gpm) capacities and costs of commercially available aluminum mainline. The pipe diameter required for a given system was based on total pump gpm; the smallest diameter pipe with capacity greater than or equal to required gpm was selected. The length of mainline required was based on the following assumptions:

1. The distance from the pump to the disposal site is 300 feet.
2. All disposal sites for hand move, side roll, and big gun systems are square.
3. The disposal site for a traveling big gun is rectangular, width being limited to 1620 feet by the length of the flexible irrigation base. (A maximum hose length of 660 feet allows a travel path of 1320 feet, which when added to a 300 foot wetted diameter equals 1620 feet.)
4. Mainline for the hand move and side roll systems must extend the length of the disposal site.
5. Mainline for the big gun system must extend the length plus the width of the disposal site.

Using these assumptions, the length of mainline (feet) required for the various systems was calculated as follows:

1. Hand move and side roll systems:

$$LMAINA = 300 + [(ADS)(43560)]^{1/2}$$

where:

LMAINA = feet of mainline required for hand move and side roll systems

300 = distance from pump to the edge of the disposal site

ADS = area of the disposal site in acres

43560 = $ft.^2$/acre

2. Stationary big gun:

$$LAMINB = 300 + 2[(ADS)(43560)]^{1/2}$$

where:

LMAINB = feet of mainline required for big gun systems

300 = distance from the pump to the disposal site in feet

ADS = disposal site area in acre

43560 = $ft.^2$/acre

3. Traveling big gun:

$$LAMINC = 300 + [(ADS)(43560)]/1620$$

where:

LAMINC = feet of mainline required for traveling big gun systems

300 = distance from the pump to the disposal site in feet

and

$[(ADS)(43560)]/1620$ is the length of the disposal site as:

ADS = disposal site area in acres

43560 = $ft.^2/acre$

1620 = width of the disposal site in feet

The total cost of mainline for any system was the lineal feet required, multiplied by the per foot cost as determined by pipe diameter, selected as described.

Miscellaneous Items

Fencing. Fencing was assumed to be required for the retention pond and perimeter. Given the area occupied by pond and perimeter at $(L+101)^2$, the lineal feet of fence, LF, required was calculated:

$$LF = 4(L+101).$$

The total cost of fencing was calculated on a per lineal foot basis, the cost of which includes materials and installation.

Seeding and Erosion Control. Seeding the exposed earthwork to grass is assumed to be required to prevent erosion. The cost was calculated as 1% of the total cost of earthwork.

Engineering. A fixed cost of $200 was included to cover surveying and other travel, etc., associated with construction of facilities. No engineering costs were included for design of the earthworks or disposal system. Such costs would be highly site specific and in most cases, U.S. Soil and Water Conservation or University Extension personnel are available to perform these duties at no cost to the feedlot operator.

Settling Basin Check Dams. It was assumed that two expanded-metal screen dams were installed in each settling basin, with total feet of check dams equal to twice the width of the basin. The cost was calculated on a per foot basis which includes materials and installation. Settling basins widths are those described in the calculation of land area occupied by the settling basin.

Annual Operating Costs

Operating and ownership costs were grouped into six categories:

1. Interest and depreciation
2. Repair and maintenance
3. Taxes
4. Insurance
5. Labor
6. Energy

Interest and Depreciation

The cost of depreciation and interest was expressed as a series of equivalent annual costs, amortizing the principal and interest payments over the lifetime of the investment. This was calculated by multiplying the total investment by an amortization factor, reflecting a lifetime of ten years and a 10% interest rate for all items. All items were assumed to have zero salvage value at the end of ten years.

The actual lifetimes of some investment items are in excess of ten years. However, all items were depreciated over the ten year period to reflect the uncertainty that exists with respect to future prices, irrigation and waste disposal technology, livestock production practices, and other institutional factors. These may alter what are now socially acceptable forms of waste disposal.

All items except the traveling big gun are assumed to require no periodic replacement during their assigned lifetimes. The traveling big gun utilizes a flexible irrigation hose which has a lifetime of 2 to 5 years, depending on soil conditions and operating practices. For this study, a lifetime of 3 years was assumed.

To account for replacement of the flexible irrigation hose used for the traveling big gun system, the initial cost of the system includes the cost of replacing the hose in 4 and 7 years following the initial purchase. This cost is the sum of the present values of the hose, discounted at 10% for the appropriate number of years. (See Table 3 of Appendix A for details.)

Repair and Maintenance

Repair and maintenance costs were calculated on the basis of initial investment using the following coefficients (Pair, 1975)

A. Pumps: 6%

B. Mainline: 2%

C. Hand move laterals: 2%

D. Side roll laterals: 3%

E. Big guns: 2%

F. Traveling big gun: 3%

G. Earthworks: 0.5%

Taxes

An annual cost for property taxes was calculated by assuming a uniform tax rate of 1.5%, applied to the full value of all land and to one-half the value of all other investment items.

Labor

In addition to labor costs represented in maintenance and repair, labor was required for operating all irrigation systems. Using labor requirements estimated for the hand move, big gun and traveling big gun systems by Lorimer (1974) and for the side roll system by Gossett and Willett (1976), cost equations were developed to calculate labor costs for each system. Labor requirements for each system are summarized in Table 6.

Table 6. Labor requirements for operating various irrigation systems.

System	Area/set	Labor/set (min.)	Labor/acre (hours)
Hand move*	1.8	70	0.65
Side roll**	1.8	20	0.18
Stationary big gun***	2.2	70	0.53
Traveling big gun****	10.0	60	0.10

* 1320 ft. lateral with 60 ft. between sets.
** 1320 ft. lateral with 60 ft. between sets.
*** 350 ft. wetted diameter.
**** 356 ft. wetted diameter and 1320 ft. travel.

Hand Move. With 70 minutes required per 1.8 acre set (0.633 hour per acre), the labor required per pumping day is equal to

$$0.65\,(ADP)$$

where:

$$ADP = \text{disposal plot area.}$$

Yearly labor cost, CLABHM, is represented by the following equation:

$$CALBHM = 0.65(ADP)(PDAYS)(COST\ N)$$

where:

PDAYS = number of pumping days per year

COST N = hourly wage rate

Side Roll. Doran estimates labor requirements for the side roll system (1320 foot lateral 60 foot move) at 20 minutes per lateral per move.

Since the operator is required only to start and stop the power unit which advances the lateral to the next set, labor requirements were calculated not on a per-acre basis, but with respect to the number of laterals. With a maximum lateral length of 1320 feet (1.8 acres per set), the number of laterals, N, is represented by one of the following FORTRAN equations:

(7a)* N = IFIX(ADP/1.8+1)

(7b)** $N = \left(\frac{0.5ADP}{1.8} + 1\right)$ = IFIX(.278ADP+1)

The annual cost of labor was then calculated by one of the following equations:

CLABSOR = [(COST N)(PDAYS)(.33)]IFIX($\frac{ADP}{1.8}$ +1)*

CLABSOR = [(2)(COST N)(PDAYS)(.33)]IFIX(.278ADP = 1)**

where: 0.33 = hours required to move each lateral and other variables as previously defined.

* ADP irrigated in 1 set

** ADP irrigated in 2 sets

Stationary Big Gun. Using the value of 0.53 hr./acre from Table 6, labor required per pumping day equals 0.53 (ADP). Yearly labor cost, CLABBG, was calculated as follows:

$$CLABBG = 0.53(ADP)(PDAYS)(COST\ N)$$

with all variables defined as above.

Traveling Big Gun. Using the labor requirement of one hour per day per unit, the annual cost of labor, CLABTG, was calculated as follows:

$$CLABTG = (NMBG)(PDAYS)(COST\ N)$$

where:

NMBG = number of traveling big guns required for the system

PDAYS = average number pumping days per year

COST N = hourly wage rate

Labor costs for all systems were calculated under the assumption that each day the system is operated, the sprinkler units are moved to the adjacent disposal plot. For the hand move and big gun systems, labor costs are the same regardless of whether the disposal plot is covered in one or two sets. With systems designed to cover the disposal plot in two sets, two moves are required but only half as much equipment is moved as when plot is covered with one set. All systems were assumed to require a minimum of one hour of labor per pumping day.

Energy

The annual cost of energy represents the cost of electricity used for pumping. Energy requirements for pumping were based on the three parameters: 1) total volume pumped, 2) total feet of dynamic head the system is pumping against, and 3) the efficiency of the pump and its drive unit. Energy is equal to force times distance, thus the amount of energy required to lift one acre-inch of water one foot equals

E = [(1 acre-inch)(27,158 gal. /acre-inch)(8.337 lgs. /gal.)](1 foot)
 = 226,497.72 foot-lbs.[10/]

Converting to horsepower-hour;

E = (226,497.72 foot lobs.)/(33,000 foot-lbs. /min-HP)(60 min/hr.)
$E = 1.14393 \times 10^{-1}$ HP-hour per acre-inch per foot of lift

Converting this relation to kilowatt-hours,

[10/] All conversion factors are from the Handbook of Chemistry and Physics, 52nd Edition. 1971. Chemical Rubber Company, Cleveland, Ohio.

$E = (1.4393 \times 10^{-1}$ HP-hr.)(1 kilowatt-hour/1.34 Hp-hr.)

$E = 8.5368 \times 10^{-2}$ kilowatt hours per acre inch per foot of lift

With feet of lift represented by the total feet of dynamic head, (previously calculated in the section describing pump selection) and assuming a pump efficiency of 70% and a motor efficiency of 88%, (61.6% combined efficiency), the per acre-inch cost of energy for pumping equals

$$CELEC = \frac{(8.5368 \times 10^{-2})(TDH)(CKWH)}{0.616}$$

$$= 0.138\ (TDH)(DKWH)$$

where:

CELEC = dollar cost per acre inch pumped

8.5368 = kilowatt hours required to lift 1 acre-inch of water one foot at 100% efficiency

TDH = Total Dynamic Head in feet

CKWH = cost per kilowatt-hour

0.616 = combined efficiency of pump and motor

Energy costs at any site were calculated using the appropriate feet of head as calculated in the pump section and using the average acre-inches pumped per year as provided by the Feedlot Runoff Design program.

V. MODEL OUTPUT AND ANALYSIS

Model Output

The cost estimating model analyzed five management pumping policies at seven selected locations which satisfy the 1983 EPA guideline of allowing runoff only in connection with a 25 year-24 hour storm. For each location, the model evaluated initial investment and annual cost of feedlot control designs with daily pumping rates of 5, 10, 20, 40 and 100 percent of the volume resulting from 25 year-24 hour storm. Tables 7 and 8 compare the annual costs (dollars per head of capacity) for management policies 1 and 1f (see Table 4) at two locations at various pumping rates and feedlot sizes. Tables 9-12 show the annual cost (dollars per head of capacity) for management policy 1 with the above pumping rates at selected locations. Table 13 presents a comparison of least cost disposal systems (dollars per head of capacity per year) for each management policy at Ames, Iowa and Lubbock, Texas. Table 14 shows the cost of each irrigation disposal system on .405, 4.05, and 40.5 hectare feedlots using management policy 7 (apply effluent to a hay crop without winter disposal) at each of the seven stations when pumping is limited to a maximum of ten days per year. Table 15 presents the disposal system which is least cost with respect to initial investment per head of capacity and annual cost per head of capacity for approximately equivalent pumping rates under management policy 1 (permitting all-year pumping) at each location. Table 17 lists the estimated added costs of production (dollars per head) for six locations and three feedlot sizes. Figure 6 shows the costs of various levels of runoff control and the simulated performance of those systems for a 40.5 hectare feedlot in Pendleton, Oregon. The systems range from 100% control (full compliance with EPA regulations) to zero control.

Table 7. Annual pollution control cost (dollars per head of capacity)[a] at Ames, Iowa as a function of pumping capacity, feedlot size, and management alternative.[b]

Pumping Rate m^3/feedlot ha-day[c]	Feedlot size, ha 0.405		4.05		40.5	
	Management Alternative 1	1f	1	1f	1	1f
68.5	4.57	4.38	1.64	1.51	1.30	1.16
137	4.55	4.51	1.76	1.67	1.55	1.53
274	4.70	4.66	2.00	2.00	2.00	2.01
548	5.21	5.26	2.54	2.65	2.79	2.90
1370	6.30	7.00	4.30	5.06	5.44	6.32

[a] Assumes a feedlot capacity of 494 head per hectare (200/acre).

[b] All-year pumping policy with nutrient utilization policy; dashes indicate system not applicable. Management alternative 1 represents pumping year round whenever weather conditions permit and if at least one day's pumping volume is in the retention pond. Alternative 1f is identical to alternative 1 except it allows pumping when less than a full day's pumping volume is in the pond.

[c] Pumping rates represent 0.05, 0.1, 0.2, 0.4, and 1.0 times the 25 year-24 hours storm. Multiply by 0.00394 to convert to acre-inches/feedlot acre-day. All systems use hand move irrigation system.

Table 8. Annual pollution control cost (dollars per head of capacity)[a] at Lubbock, Texas as a function of pumping capacity, feedlot size, and management alternative.[b]

Pumping Rate	Feedlot Size, ha					
	0.405		4.05		40.5	
	Management Alternative					
m^3/feedlot ha-day[c]	1	1f	1	1f	1	1f
63.5	4.32	4.29	1.45	1.41	1.09	1.06
127	4.37	4.32	1.50	1.46	1.22	1.19
254	4.46	4.44	1.70	1.74	1.58	1.61
508	4.92	4.92	2.21	2.27	2.28	2.41
1270	5.45	5.86	3.43	3.89	4.35	4.83

[a] Assumes a feedlot capacity of 494 head per hectare (200/acre).

[b] All-year pumping policy with nutrient utilization policy; dashes indicate systm not applicable. See text for explanation of management alternatives 1 and 1f.

[c] Pumping rates represent 0.05, 0.1, 0.2, 0.4, and 1.0 times the 25 year-24 hours storm. Multiply by 0.00394 to convert to acre-inches/feedlot acre-day. All systems use hand move irrigation system.

Table 9. Annual pollution control cost (dollars per head of capacity)[a] at Ames, Iowa as a function of pumping capacity, irrigation system, and feedlot size.[b]

Pumping Rate m^3/feedlot ha-day[c]	Irrigation System[d]	Feedlot Size, ha .405	4.05	40.5
68.5	1	4.57	1.64	1.30
	2	--	1.72	1.34
	3	5.13	1.69	1.41
	4	--	--	1.42
137	1	4.55	1.70	1.44
	2	--	1.84	1.58
	3	5.06	1.84	1.64
	4	--	--	1.65
274	1	4.70	2.00	2.00
	2	--	2.33	2.32
	3	5.10	2.13	2.40
	4	--	--	2.17
548	1	5.21	2.54	2.79
	2	5.93	3.23	3.47
	3	5.16	3.49	3.34
	4	--	3.40	3.24
1,370	1	6.30	4.30	5.54
	2	8.07	6.07	7.31
	3	6.81	4.82	6.93
	4	--	5.68	7.23

[a] Assumes a feedlot capacity of 494 head per hectare (200/acre).

[b] All-year pumping policy with nutrient utilization policy; dashes indicate system not applicable.

[c] Pumping rates represent 0.05, 0.1, 0.2, 0.4, and 1.0 times the 25 year-24 hour storm. Multiply by 0.00394 to convert to acre-inches/feedlot acre-day.

[d] Irrigation systems: 1 = hand move; 2 = side roll; 3 = big gun; and 4 = traveling big gun.

Table 10. Annual pollution control cost (dollars per head of capacity)[a] at Experiment, Georgia as a function of pumping capacity, irrigation system, and feedlot size.[b]

Pumping Rate m^3/feedlot ha-day[c]	Irrigation System[d]	Feedlot size, ha .405	4.05	40.5
85	1	4.91	1.92	1.67
	2	--	1.98	1.70
	3	5.57	2.10	1.88
	4	--	--	1.95
170	1	4.73	1.83	1.84
	2	--	1.98	1.99
	3	5.32	2.02	2.19
	4	--	--	2.25
340	1	4.83	2.15	2.35
	2	--	2.52	2.71
	3	5.30	2.43	2.94
	4	--	3.30	3.42
680	1	5.30	2.72	3.61
	2	6.18	3.54	4.43
	3	5.28	3.21	4.21
	4	--	3.56	4.87
1,700	1	7.03	6.35	7.60
	2	9.20	8.52	9.76
	3	7.47	6.54	10.19
	4	--	6.66	11.95

[a]Assumes a feedlot capacity of 494 head per hectare (200/acre).

[b]All-year pumping policy with nutrient utilization policy; dashes indicate system not applicable.

[c]Pumping rates represent 0.05, 0.1, 0.2, 0.4, and 1.0 times the 25 year-24 hour storm. Multiply by 0.00394 to convert to acre-inches/feedlot acre-day.

[d]Irrigation systems: 1 = hand move; 2 = side roll; 3 = big gun; and 4 = traveling big gun.

Table 11. Annual pollution control cost (dollars per head of capacity)[a] at Lubbock, Texas as a function of pumping capacity, irrigation system, and feedlot size.[b]

Pumping Rate m^3/feedlot ha-day[c]	Irrigation System[d]	Feedlot Size, ha .405	4.05	40.5
63.5	1	4.28	1.40	1.05
	2	--	1.48	1.11
	3	4.80	1.43	1.14
	4	--	--	1.17
127	1	4.26	1.40	1.14
	2	--	1.55	1.28
	3	4.75	1.52	1.28
	4	--	--	1.39
254	1	4.25	1.53	1.43
	2	--	1.85	1.75
	3	4.62	1.60	1.61
	4	--	--	1.69
508	1	4.68	2.03	2.17
	2	5.35	2.69	2.84
	3	4.64	2.03	2.49
	4	--	2.98	2.77
1,270	1	5.43	3.42	4.34
	2	7.10	5.08	6.00
	3	6.03	3.73	5.03
	4	--	5.24	4.94

[a] Assumes a feedlot capacity of 494 head per hectare (200/acre).

[b] All-year pumping policy with nutrient utilization policy; dashes indicate system not applicable.

[c] Pumping rates represent 0.05, 0.1, 0.2, 0.4, and 1.0 times the 25 year-24 hour storm. Multiply by 0.00394 to convert to acre-inches/feedlot acre-day.

[d] Irrigation systems: 1 = hand move; 2 = side roll; 3 = big gun; and 4 = traveling big gun.

Table 12. Annual pollution control cost (dollars per head of capacity)[a] at Pendleton, Oregon as a function of pumping capacity, irrigation system, and feedlot size.[b]

Pumping Rate m^3/feedlot ha-day[c]	Irrigation System[d]	Feedlot Size, ha		
		.405	4.05	40.5
19	1	3.48	.70	.35
	2	--	--	--
	3	3.97	.75	.36
	4	--	--	--
38	1	3.49	.72	.37
	2	--	--	.42
	3	3.92	.74	.38
	4	--	--	.49
76	1	3.52	.75	.44
	2	--	.85	.53
	3	3.93	.82	.47
	4	--	--	.57
152	1	3.59	.87	.61
	2	--	1.07	.81
	3	3.94	.92	.66
	4	--	--	.76
380	1	4.02	1.24	1.16
	2	--	1.74	1.66
	3	3.97	1.19	1.20
	4	--	2.43	1.35

[a]Assumes a feedlot capacity of 494 head per hectare (200/acre).

[b]All-year pumping policy with nutrient utilization policy; dashes indicate system not applicable.

[c]Pumping rates represent 0.05, 0.1, 0.2, 0.4, and 1.0 times the 25 year-24 hour storm. Multiply by 0.00394 to convert to acre-inches/feedlot acre-day.

[d]Irrigation systems: 1 = hand move; 2 = side roll; 3 = big gun; and 4 = traveling big gun.

Table 13. Minimum annual pollution control cost (dollars per head of capacity)[a] for various disposal policies for Ames, Iowa and Lubbock, Texas.

Station	Management Alternative[b]	Disposal Policy[c]	Feedlot Area, ha		
			.405	4.05	40.5
Ames, IA	1	NU	4.57	1.64	1.30
(pumping rate,	4	NU	4.92	1.96	1.50
68.5 m^3/feedlot ha-day)	5	NU	4.72	1.78	1.42
	6	NU	4.54	1.64	1.43
	7	NU	4.54	1.63	1.28
	1f	SWD	5.08	2.20	1.86
	7	SWD	5.08	2.22	1.86
Lubbock, TX	1	NU	4.32	1.45	1.09
(pumping rate,	2	NU	4.32	1.45	1.09
63.5 m^3/feedlot ha-day)	3	NU	4.35	1.46	1.10
	6	NU	4.31	1.43	1.07
	7	NU	4.29	1.42	1.06
	1f	SWD	4.67	1.85	1.49
	7	SWD	4.70	1.88	1.51

[a]Assumes a feedlot capacity of 494 head per hectare (200/acre).

[b]Management alternatives are defined in Table 4.

[c]Disposal application rates: NU = nutrient utilization (224 kg of nitrogen/ha) and SWD = strict waste disposal (1,344 kg of nitrogen/ha).

Table 14. Annual pollution control costs (dollars per head of capacity)[a] when pumping ten or fewer days per year for various irrigation systems at seven U.S. locations.[b]

Location	Dewatering day/year	Pumping Rate m^3/feedlot ha-day	Irrigation System[c]	Feedlot size, ha		
				.405	4.05	40.5
Ames, IA	10.0	274.0	1	4.70	2.00	2.00
			2	--	2.33	2.32
			3	5.10	2.13	2.40
			4	--	--	2.17
Astoria, OR	7.5	140.0	1	10.64	8.45	10.14
			2	12.34	10.13	11.82
			3	11.38	9.43	12.51
			4	--	9.79	14.38
Bozeman, MT	7.6	138.0	1	4.25	1.45	1.18
			2	--	1.61	1.34
			3	4.70	1.55	1.31
			4	--	--	1.34
Corvallis, OR	8.2	456.0	1	6.23	3.41	3.48
			2	--	3.96	4.03
			3	6.29	3.54	3.98
			4	--	4.32	3.88
Experiment, GA	7.6	680.0	1	6.23	3.52	4.29
			2	7.10	4.34	5.11
			3	6.10	3.97	4.80
			4	--	4.34	5.25
Lubbock, TX	8.9	127.0	1	4.31	1.44	1.17
			2	--	1.59	1.32
			3	4.78	1.56	1.30
			4	--	--	1.42
Pendleton, OR	9.4	38.0	1	3.53	.80	.44
			2	--	--	.49
			3	3.97	.81	.45
			4	--	--	.56

[a] Assumes a feedlot capacity of 494 head per hectare (200/acre).
[b] Management policy: apply effluent to hay crop without winter disposal.
[c] Irrigation systems: 1 = hand move; 2 = side roll; 3 = big gun; 4 = traveling big gun.

Table 15. Minimum investment and annual pollution control cost (dollars per head of capacity)[a] at seven U. S. locations.

Location	Feedlot Size, ha: .405 Investment	.405 Annual Cost	4.05 Investment	4.05 Annual Cost	40.5 Investment	40.5 Annual Cost
Ames, IA	22.91	4.54	8.41	1.63	6.59	1.28
Astoria, OR	37.93	7.47	23.08	4.53	23.15	4.50
Bozeman, MT	20.81	4.11	6.70	1.27	4.91	0.92
Corvallis, OR	25.58	5.06	11.12	2.15	9.65	1.88
Experiment, GA	23.40	4.73	8.69	1.83	8.16	1.67
Lubbock, TX	21.85	4.29	7.52	1.42	5.68	1.06
Pendleton, OR	17.74	3.48	3.65	0.70	1.84	0.35

[a]Assumes a feedlot capacity of 494 head per hectare (200/acre).

Table 16. Annual pollution control costs (dollars per head of capacity)[a] at seven U.S. locations with similar pumping capacities.

Location	Dewatering day/year	Pumping Rate m^3/feedlot ha-day	Irrigation System[b]	Feedlot Size, ha		
				.405	4.05	40.5
Ames, IA	10.3	274	1	4.70	2.00	2.00
			2	--[c]	2.33	2.32
			3	5.10	2.13	2.40
			4	--	--	2.17
Astoria, OR	37.7	280	1	7.51	4.57	4.74
			2	--	4.80	4.93
			3	8.15	4.93	5.57
			4	--	--	5.62
Bozeman, MT	3.6	276	1	4.21	1.57	1.52
			2	--	1.92	1.87
			3	4.55	1.62	1.79
			4	--	--	1.61
Corvallis, OR	17.3	228	1	5.06	2.22	2.07
			2	--	2.47	2.31
			3	5.55	2.39	2.42
			4	--	--	2.36
Experiment, GA	15.7	340	1	4.83	2.15	2.35
			2	--	2.52	2.71
			3	5.30	2.43	2.94
			4	--	3.30	3.42
Lubbock, TX	4.4	254	1	4.25	1.53	1.43
			2	--	1.85	1.75
			3	4.62	1.60	1.61
			4	--	--	1.69
Pendleton, OR	1.5	380	1	4.02	1.24	1.16
			2	--	1.74	1.66
			3	3.97	1.19	1.20
			4	--	2.43	1.35

[a]Assumes a feedlot capacity of 494 head per hectare (200/acre).

[b]Irrigation systems: 1 = hand move; 2 = side roll; 3 = big gun; 4 = traveling big gun.

[c]Dashes indicate system not applicable.

Table 17. Added production cost (dollars per head)[a] associated with pollution control systems[b] as a function of feedlot size, location.

Feedlot Location	Feedlot Size, ha		
	0.405	4.05	40.5
Ames, Iowa	1.52	.55	.43
Bozeman, Montana	1.39	.43	.31
Corvallis, Oregon	1.78	.77	.64
Experiment, Georgia	1.64	.64	.56
Lubbock, Texas	1.43	.47	.35
Pendleton, Oregon	1.16	.23	.12

[a]Assumes a feedlot capacity of 494 head per hectare (200/acre), three times yearly animal turnover and 100% use of capacity.

[b]All systems are the least cost system for each location: pumping rate equals .05 x 25 year - 24 hour storm, irrigation system 1, management alternative 1, and a nutrient utilization disposal policy.

Interpretation of Output

Storage Volume vs. Pumping Capacity

Tables 9-12 present the effects of increasing pumping rates on the total cost of each system. In most cases, large pumping capacities substantially increased the annual cost of the runoff control system. At all but one location, the majority of designs reached minimum (or near minimum) feedlot runoff control costs with daily pumping rates of 0.1 times the 25 year-24 hour storm. The Feedlot Runoff Design Program (see Wensink and Miner, 1976) did not permit pumping unless a full day's pumping volume was available in the reservoir. This constraint effectively makes the minimum pond volume equal to the daily pumping rate. Though this constraint was included to more accurately model pragmatic feedlot operations, this limitation did not permit a complete substitution of feedlot reservoir volume for pumping rates. Wensink and Miner (1976) showed that increasing pumping rates did not, in general, decrease volumes, since chronic precipitation conditions, rather than single catastrophic storms, determined runoff reservoir volumes. In selected cases, reservoir capacities required actually increased as pumping rates were enlarged.

Management policy 1f was developed to more accurately reflect the potential substitution of pumping capacity for pond volume by allowing pumping when less than a full day's pumping volume was contained in the pond. Tables 7 and 8 show the costs associated with systems designed to operate under policies 1 and 1f from Ames, Iowa and Lubbock, Texas. These tables illustrate the same pattern as seen in Tables 9 through 12; increases in pumping capacity are almost always accompanied by increased cost.

The fact that the costs are so close for policy 1 and 1f in each situation suggests that the cost of the retention pond is a small part of the total cost. Thus, even a 50% or 75% reduction in pond cost will result in a negligible effect on the total cost of the system.

At Astoria, Oregon, minimum cost designs occurred with pumping rates of 0.2 times the 25 year-24 hour storm on feedlot sizes of .405 and 4.05 ha. This is primarily the result of the atypical nature of the station (annual precipitation, 191.5 cm). Isolated examples of cost decreases accompanying increasing pumping rates also existed at selected stations (Corvallis, OR) with .405 ha feedlots. This result may be an artifact of the cost estimating program; the program's minimum size irrigation system provided sufficient capacity to permit higher pumping rates. The increase in pumping rates decreased the number of pumping days and consequently, total labor cost.

The above data suggest that pumping capacity cannot economically substitute for reservoir volume except in extreme cases. The economic viability of open beef feedlots at stations with extreme precipitation (Astoria, OR) is very questionable.

Economics of Size

Tables 9-14 show significant economies of size for controlling feedlot runoff. There are also consistent diseconomies at higher pumping rates, but at lower pumping rates, economies of size were consistent. Most of the size advantage was achieved by increasing feedlot size to 4.05 hectare (2000 head capacity). Pendleton, Oregon (annual precipitation, 34 cm) deviated from this generalization in that a significant economy was achieved by increasing feedlot size to 40.5 hectares (100 acres). This is due to its low runoff and minimal pumping rates.

Ames, Iowa is representative of the remaining stations with respect to this point. The annual cost (least cost system) per head of capacity for the 4.05 hectare feedlot is only 28% of the cost for the 0.405 hectare lot, while the cost for the 40.5 hectare lot is 78% of that associated with the 4.05 hectare lot. In this case, the total reduction in annual cost per head of capacity achieved by increasing feedlot size from 0.405 to 40.5 hectares is $3.27. Of this $3.27, 90% is accounted for by increasing feedlot size from 0.405 to 4.05 hectares. Thus, small farmer feeders are affected by control substantially more than larger commercial feeders. However, economies of size are quickly achieved and these data indicate most commercial-sized lots in similar physical locations will face substantially the same costs per head, regardless of feedlot size.

Geographic Location

Comparisons between different geographic locations show significant variations in costs. Table 15 presents the least cost runoff control and disposal system for each location. This includes all pumping rates, management alternatives, disposal policies, and irrigation systems. The required investment per head ranges from $37.93 at Astoria, Oregon to $17.74 at Pendleton, Oregon for .405 ha feedlots. For 4.05 ha feedlots, minimum investment per head ranges from $23.08 at Astoria, Oregon to $3.65 at Pendleton, Oregon, and for the 40.5 ha feedlots, investment per head ranges from \$23.15 to \$1.84 for Astoria and Pendleton, Oregon, respectively.

A significant portion of the cost differences was due to variation in pumping rates. Table 16 presents the expected annual costs per head of capacity for all locations, with pumping rates approximately equated. The maximum cost differential between locations with equivalent pumping rates was \$3.54, \$3.38, and \$3.56 per head of capacity for .405, 4.05, and 40.5 ha feedlots, respectively.

If Corvallis and Astoria, Oregon are excluded from the analysis, (they are not representative of regions where open feedlots are common) costs are even more comparable. Without these stations, maximum differences in annual cost per head of feedlot capacity were \$.81, \$.98, and \$1.16 for .405, 4.05, and 40.5 ha feedlots, respectively. These cost differences are 20%, 79%, and 103% of the lowest cost location in each size category. The increasing cost differential indicates the geographic component of feedlot runoff control costs is more important for larger lots, with the arid regions having the lowest cost.

This also indicates that imposition of feedlot runoff control regulations may alter the current comparative advantage the midwest has over the arid southwest. Feed costs in the midwest are usually lower than in the southwest, giving midwest feedlot operators a comparative advantage over southwest feedlot operators. The higher runoff control costs faced by midwest feedlot firms will reduce this advantage.

Management Alternatives

A comparison of the expected annual costs for various management alternatives is presented in Table 13 for two locations, Ames, Iowa and Lubbock, Texas. Ames represents the Midwest, where small feedlots predominate; Lubbock typifies the Southwest, where large feedlots are more common. The pumping rates at each station were almost identical, so irrigation technology was equivalent at each site. Table 13 indicates that Lubbock had an absolute cost advantage in every management policy, but the differences in expected costs were less than 20% in most cases. Economies of size were more pronounced at Lubbock, so the cost differential between Ames and Lubbock is more significant for large feedlot sizes.

At each station, the costs of using the various management alternatives were fairly uniform, deviating by no more than 8%. There appears to be no economic incentive strictly on the basis of annual costs for selecting any particular management alternative. The data suggest that an operator could build the system to match the most flexible management alternatives (pumping only in the summer months) at little extra cost, and could then be free to switch to another management alternative at a later date, if desired.

Disposal Policy

Table 13 also contains the annual cost per head of capacity for a "strict waste disposal" policy in conjunction with management alternatives 1 (all-year disposal) and 7 (apply effluent to a hay crop without winter disposal). The strict disposal policy permitted a maximum of 1,344 kg of nitrogen per hectare and added the cost of the land occupied by the disposal site to the total runoff control system cost. Table 13 indicates that the "strict disposal" policy is more expensive (especially for the larger feedlots) than the "nutrient utilization" policy. The cost differences between the least cost nutrient utilization system and the least cost "strict waste disposal" system increase with increasing feedlot size. At Ames, Iowa, this cost difference is 12%, 26%, and 45% for the 0.405, 4.05, and 40.5 hectare lots, respectively. At Lubbock, Texas, cost differences of 9%, 30%, and 41% are shown.

As explained in Chapter IV, in calculating the total investment for runoff control systems using a nutrient utilization disposal policy, no charge is made for land used for disposal. For control systems using the "strict waste disposal" policy, the cost of this land is charged to the system and its amortized cost is part of the annual cost of that system.

For both locations, the cost of land was assumed to be $1,852 per hectare ($750/acre); this may be too low for Ames and too high for Lubbock. If more realistic land prices were used, strict waste disposal would be more costly than shown at Ames and less costly than shown for Lubbock.

The outlays shown for the nutrient utilization policy did not consider the fertilizer value of the runoff applied to cropland. If this were done, the cost differential between nutrient utilization and strict waste disposal would be more significant than shown in Table 13.

Irrigation Systems

The hand move irrigation system is consistently the least expensive to own and operate, as seen in Tables 9-14. The stationary big gun is next, followed by the side roll and traveling big gun systems. The stationary big gun system is commonly used for waste disposal, but it appears more costly due to higher pump costs and the increased mainline required.

In a few cases (see Tables 9, 11 and 12) on 40.5 ha feedlots, the traveling big gun system was less costly than the side roll and stationary big gun. However, the traveling big gun operated 22 hours per day, while other systems operated only 12 hours per day. Longer operating conditions permitted the traveling big gun to run at lower discharge rates, and subsequently to use smaller pumps and mainlines. The traveling big gun was superior in those isolated cases in which the other disposal systems operated with multiple pumps and mainlines, while the traveling big gun used single components. These pumping rates are considerably higher than normally used for conventional irrigation systems and their suitability as disposal systems is questionable, i.e., some of the higher pumping rates are equivalent to 1.26 m^3/sec (20,000 gpm) or more for the 40.5 ha feedlots.

At lower pumping rates, cost differences between the various systems were minimal. The selection of any irrigation system by an feedlot operator will be based not only on costs, but on such variables as owner preference, alternate uses, etc. Tables 9-14 suggest that as long as a feedlot operator selects a low pumping rate, the increased costs associated with the side roll, big gun, and traveling big gun (where applicable) are not significant, especially on larger feedlots.

Operator Convenience

Many feedlot operators have elected to currently empty their runoff reservoirs infrequently (Gee, 1976). Table 14 presents the annual cost at the seven stations of systems necessary to operate an average of ten or fewer days per year. The cost primarily reflects the pumping rates required to achieve this objective. Costs vary widely, but the costs at stations listed, (Ames, Bozeman, Experiment, Lubbock, and Pendleton) show the same pattern as seen in Table 16. Experiment, Georgia had the highest cost, with the remaining stations fairly close behind. Pendleton again had the lowest cost, approximately 25% less than the other stations. The Midwestern and Southwestern stations' cost data differed by only 10-15%.

Added Costs to Producing Fed Beef

One measure of the potential impact of imposing water pollution guidelines on the beef cattle industry is the relation of those costs to existing costs of production. Table 17 presents the estimated additional production cost ($/head) at six locations for the three feedlot sizes, 0.405, 4.05, and 40.5 hectares. All costs assume 100% capacity (200 head/acre and three times yearly turnover), and represent the least cost system--hand move irrigation system, all year pumping, nutrient utilization disposal policy and a pumping rate of 0.05 times the 25 year-24 hour storm at each location.

Gee (1976) has prepared recent estimates of the costs of production for the U.S. beef feedlot industry. He reports a weighted average production cost per head of $431.77 for 1976. Of this, 92% was accounted for by feed and feeder cattle, 2% was fixed and 6% of the cost varied with lot size. These estimates were developed using the assumption of 100% use of capacity.

For lots with capacity of 1000-1999 head, a total cost of $440.76 was estimated; for lots with capacity of 8,000-15,999, Gee estimated the cost of production (dollars per head marketed) at $362.39.

Comparing the average added cost of production (Table 17) for lots in the humid regions (Ames, Iowa; Experiment, Georgia; and Corvallis, Oregon) and arid regions (Lubbock, Texas; Pendleton, Oregon; and Bozeman, Montana) to Gee's estimates showed the following: For the humid locations, the average added cost of production ($/head marketed) was $.65 and $.54 for 4.05 and 40.5 hectare lots, repsectively. These costs represent 0.152% and 0.149% of the estimated total production costs for 4.05 and 40.5 hectare lots, respectively. For the aird location, the average added cost of production was $.37 and $.26 for the 4.05 and 40.5 hectare lots. This represents 0.084% and 0.072% of the estimated total per head cost of production for beef on 4.05 and 40.5 hectare lots, respectively.

These data show that the imposition of feedlot runoff control guidelines to feedlots of this size will be insignificant from the standpoint of additions to current costs of production.

The impact on small feedlot operators will be substantial. The costs shown in Table 12 assume a three times yearly animal turnover. Many small lots (farmer-feeders) feed only one group of animals per year, so their costs will be three times those shown in Table 12. For a 0.405 hectare feedlot (one acre) located at Ames, Iowa, the annual added cost of production (per head) is estimated to be $4.56 when only one group of animals is fed per year. If the lot is operated at 100% capacity--200 animals per acre--the total added cost for this size feedlot $912.00. Costs of this magnitude may force many small feedlot operators to cease feeding beef in open feedlots.

Runoff Control Costs at Varying Levels of Control

Thus far the analysis has dealt only with the costs of full compliance with proposed EPA guidelines for 1983. The literature to date has dealt only superficially with the question of the marginal cost of controlling runoff at levels representing less than full compliance with the proposed regulations. Klocke (1976) presented some "marginal cost" data with respect to changes in cost of controlling runoff at a given level for various feedlot sizes. This did point out the existence of economies of scale but did not address the question of the marginal cost of runoff control at various levels of control for the same size feedlot. Wensink and Miner (1977) investigated the effect of relaxing the performance standard on the design parameters developed with their Feedlot Runoff Design Program. They found that by excluding the worst five years of their hydrologic data (with respect to precipitation) design storage volumes were reduced by an average of 25%. This did not provide data that was economically useful, as the cost of the retention pond is a small part of the total cost of most runoff control systems.

To generate data that could potentially be used to derive the marginal cost relationships desired, Wensink and Miner's (1975)

Return Period Design Program was used to simulate the performance of runoff control systems whose design parameters are insufficient to satisfy the 1983 runoff guidelines. The performance of each system was measured as the percent of total runoff occurring during the period 1914-1971 the system would have contained.

An understanding of how this simulation model works will aid in understanding how the cost-performance relationships were developed. Figure 5 shows in simplified form the basic operation of the feedlot runoff model. Figure 6 shows a detailed flowchart of the Return Period Design Model. For each year of climatological data, the program output lists the following data:

1. Total number of reservoir overflows
2. Total number of illegal reservoir overflows
3. Inches legal reservoir overflow
4. Inches illegal reservoir overflow
5. Inches total reservoir overflow
6. Maximum reservoir depth
7. Maximum precipitation
8. Total rainfall
9. Total runoff

For each run (the sum of the years of climatic data) the output lists the following data:

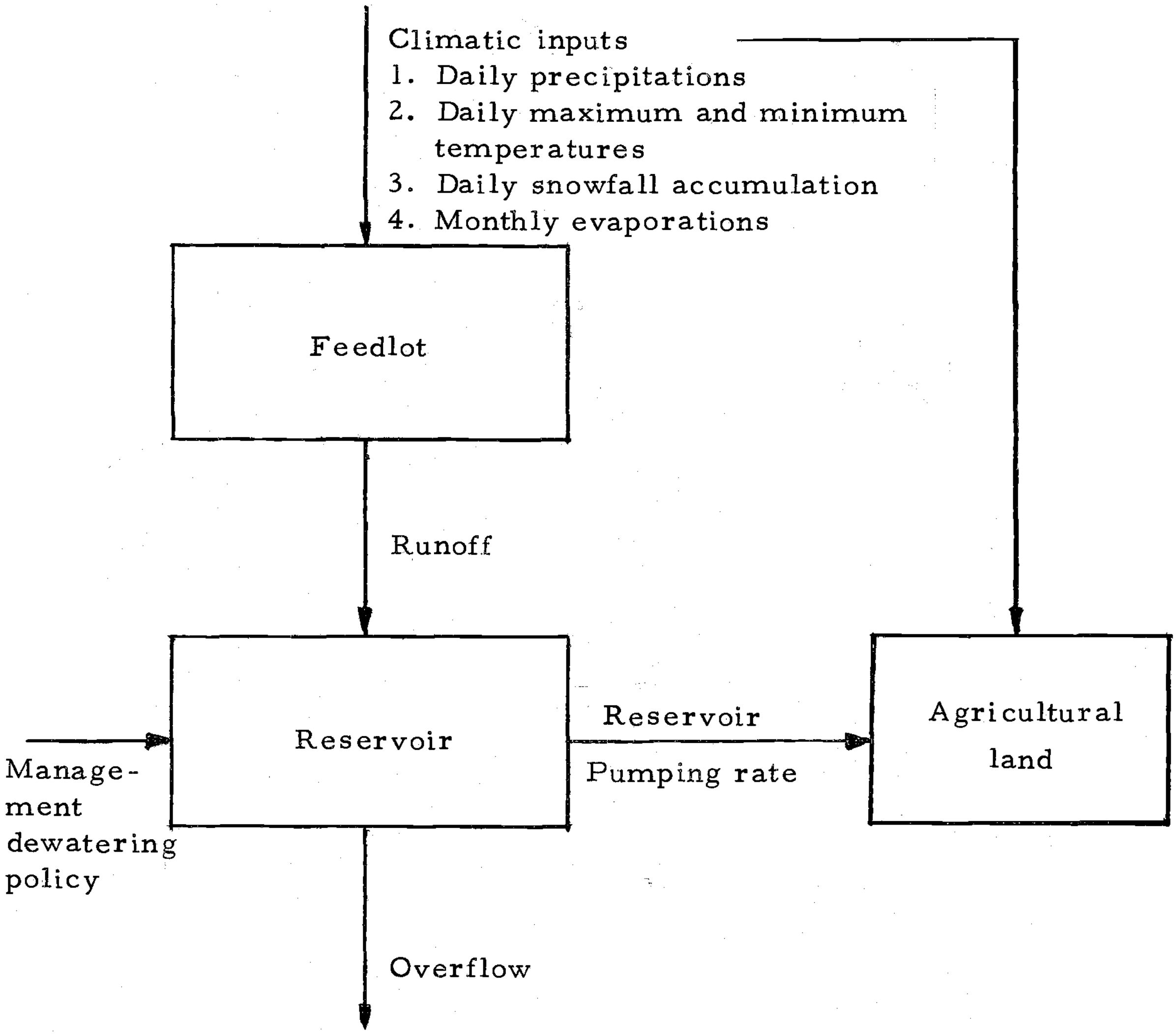

Figure 5. Block diagram of feedlot runoff model.

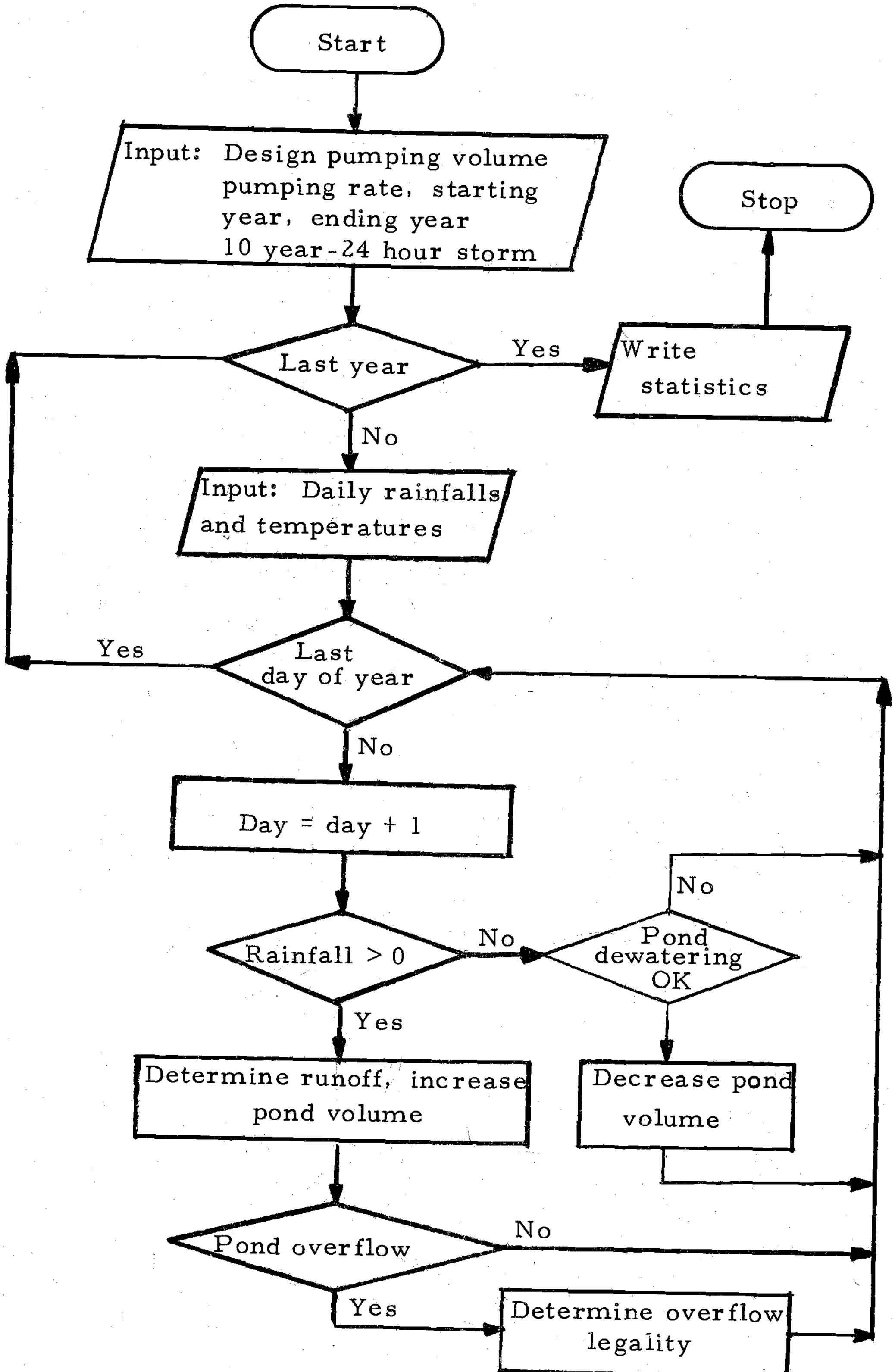

Figure 6. Flowchart of feedlot runoff retention return period design model.

1. Years simulated
2. Total rainfall
3. Total reservoir overflow
4. Total runoff
5. Average precipitation
6. Average reservoir overflow
7. Average runoff
8. Pond efficiency
9. Corrected (for legal overflow) pond efficiency

Thus by specifying the basic design parameters and management policy, a detailed summary of the simulated performance is recorded. Figure 8 was developed by combining these performance data with the estimated cost of the same systems whose performance was tested. The costs were estimated using Runoff Control Cost Model. Figure 7 illustrates how the output from each program was combined to yield the cost-performance curve in Figure 8.

Figure 8 presents the case for a 40.5 hectare feedlot in Pendleton, Oregon. The data points represent 20 runoff control systems. The design parameters were derived by reducing the pond volume and the daily pumping rate of a given system (which complied with the 1983 guidelines) by 5% increments. Thus the 20 points represent systems whose design parameters are 100, 95, 90, . . . , 5, and 0% of the pumping and pond volume necessary to meet EPA runoff

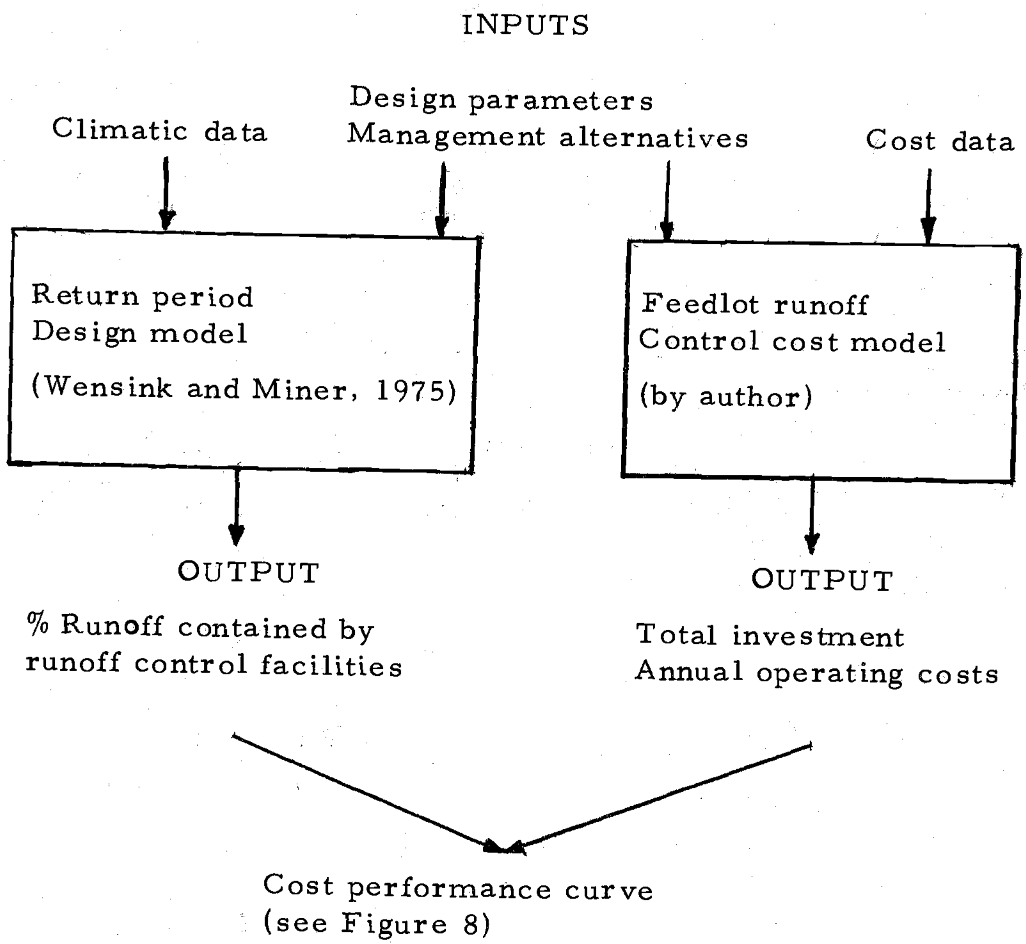

Figure 7. Block diagram illustrating the combination of output from runoff control cost model and return period design model.

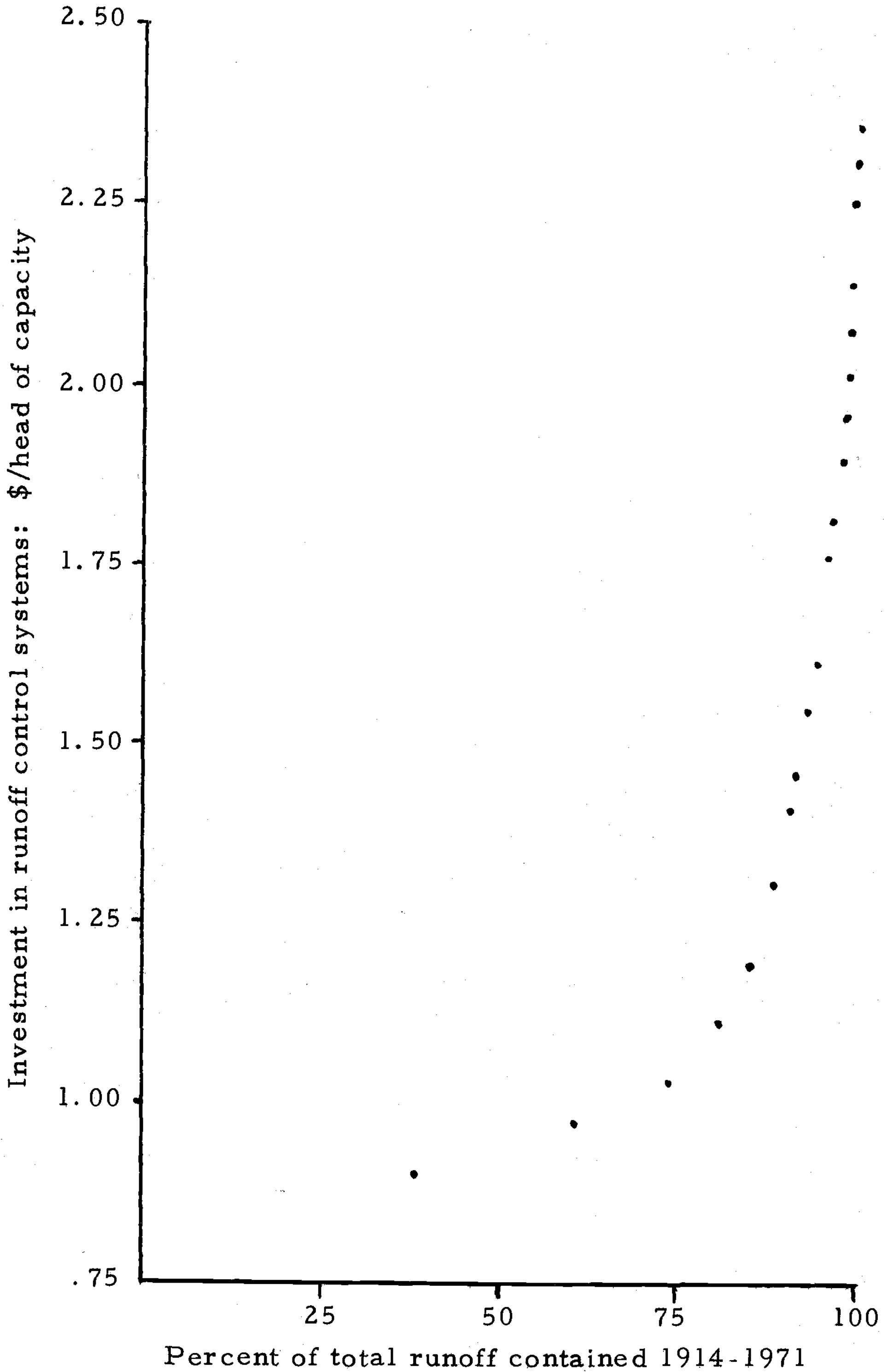

Figure 8. Simulated cost and performance of feedlot runoff control systems at Pendleton, Oregon for time period 1914-1971.

guidelines. The performance of each system was measured by the percent of total runoff that occurred in the time period (1914-1971) that the system contained. As seen in Figure 6, a large part of the investment required to achieve full compliance is spent on controlling the last very small portion of the total runoff. Of the estimated $2.34 per head investment required to control 100% of the runoff in the time period 1914-1971, $1.40 or 60% was necessary to control 90% of the runoff. To raise the level of control from 90% to 95% required an additional investment of $.35 per head--15% of the total per head cost of 100% control. To raise the level of control from 95% to 100% required an additional investment per head of $.59. This is 25% of the total per head cost for 100% control and is 1.7 times the cost of raising control from 90% to 95% containment.

These costs represent only the investment required for a runoff control system using hand move irrigation equipment, operated under management alternative 1 (all year pumping) and with the nutrient utilization waste disposal policy. Each system uses the same disposal site and disposal plot area as the full sized system. While this distorts the cost of the systems, the resulting costs are higher than would be the case if the disposal plot and site area had been recalculated for each of the 20 systems. If lower costs were used for the 19 systems which were of insufficient size to meet the runoff guidelines, the costs of controlling the last few percent of runoff would have been even more exaggerated than those shown in Figure 8. This clearly illustrates that significant reductions in cost can be achieved with only minor increases in the total runoff allowed to escape from feedlots.

Pendleton was the only site for which such analysis was conducted. It is not known whether this pattern would be consistent for all feedlot sizes or all locations.

It is interesting to speculate on the correspondence between various levels of runoff and the environmental insult to a watershed. However, such variables as the total feedlot area draining into a stream, distances between feedlots along a stream, stream characteristics--temperature, flow rate, other pollutants present, etc., --local rainfall patterns, and other factors all have an effect on the environmental insult from any runoff event. The number and interplay between these factors makes any general conclusion impossible.

VI. SUMMARY AND CONCLUSIONS

A computerized cost estimating model was developed to estimate the costs of runoff control facilities for open beef cattle feedlots. The model generates both investment and operating cost estimates for complete runoff control and distribution systems.

The model was used to estimate the costs of runoff control systems capable of meeting the proposed EPA runoff guidelines for 1983. Costs were estimated for runoff control facilities for one, ten, and 100 acre feedlots at seven U.S. locations. At each site, investment and operating costs were estimated for systems using four different irrigation systems, five pumping rates, seven management alternatives, and two disposal policies.

The resulting data were analyzed to model the effect the following seven criteria had on required investment and operating costs:

1. Pumping rate;
2. Feedlot size;
3. Geographic location;
4. Management alternative;
5. Disposal policy;
6. Irrigation system;
7. Operator convenience.

Estimated runoff control costs were also compared to current costs of production for open beef feedlots. The estimated cost and performance of runoff control facilities unable to meet 1983 guidelines were compared.

Pumping Rate of Disposal System

In nearly every case, increased pumping capacity resulted in increased costs, regardless of management policy, feedlot size, or irrigation system used. For a one acre feedlot in Ames, Iowa using the least cost system, a daily pump rate of 63.5 m^3/ha resulted in an annual cost ($/head of capacity) of $4.32 while a daily pump rate of 1270 m^3/ha had an associated annual cost ($/head of capacity) of $5.45. The cost differential is more exaggerated for larger feedlots.

Feedlot Size

At low pumping rates, there are consistent economies of size at every location except Astoria, Oregon. Most of the advantage is achieved by feedlots as small as ten acres. Small feedlots (one acre or less) will have annual costs ($/head of capacity) three to ten times higher then those faced by larger lots in the same locale.

Geographic Location

In areas where open beef feedlots are common, the effect of specific geographic location on runoff control costs increases with increasing feedlot size. Differences in cost between the stations with the lowest and highest cost for each size category are 20%, 79% and 103% for one, ten, and 100 acre lots, respectively. This fact will place midwestern feedlot operators at a disadvantage compared to feedlots in the arid West and Southwest.

Management Alternatives

Seven management alternatives specifying different pumping schedules were tested. At each station, the highest cost difference between any two alternatives, all other factors constant, was less than 8%. The alternative allowing all year pumping was consistently the least expensive. The data suggests the more elaborate pumping alternatives, simulating irrigation schedules for various crops, can be used with little additional cost.

Disposal Policy

A nutrient utilization policy assuming an annual nitrogen application rate of 224 kg/ha was compared to a strict waste disposal policy (nitrogen application 1344 kg/ha). The cost of the runoff control system under a strict waste disposal policy includes the cost of the disposal site. This cost is not included in the total cost for runoff control facilities under the nutrient utilization policy.

These two policies were compared at two stations, Ames, Iowa, and Lubbock, Texas. In all cases, the strict waste disposal policy was more costly. Minimum annual costs ($/head of capacity) were $4.32 with nutrient utilization and $4.70 with strict waste disposal for a one acre feedlot at Lubbock, Texas. The cost differential increases with increasing feedlot size. At Lubbock, strict waste disposal costs exceed nutrient utilization costs by 29% and 38% for 10 and 100 acre lots, respectively. The same pattern was observed for Ames, Iowa.

Irrigation Systems

Four conventional sprinkler irrigation systems were budgeted at each site to determine the effect choice of an irrigation system had on costs. A consistent pattern was observed; the hand move system was least costly, followed in order of increasing cost by the stationary big gun system, side roll system, and the traveling big gun. At low pump rates, the annual costs associated with various systems (other factors constant) often differed by less than 5-10%. This may be well within the limits of accuracy and precision that can be attributed to the cost estimating model.

Convenience of Operation

The costs of runoff control systems capable of providing the same degree of operator convenience vary with location. At Ames, Iowa the annual costs ($/head of capacity) of systems capable of letting feedlot operators pump ten days a year or less were $4.70, $2.00, and $2.00 for one, ten and 100 acre feedlots, respectively. Stations in arid regions had costs estimated to be 25-50% less than those for Ames, Iowa. Humid stations had costs estimated to be approximately 0.3 to 2.14 times the costs estimated for Ames, Iowa for one and 100 acre feedlots respectively.

Added Production Costs

Additions to current costs of production--$/head marketed--for ten and 100 acre feedlots at all locations were estimated to be approximately $.60/head for the humid areas and $.30/head for arid regions. The figures represent about .15% and .075% of current costs of production. From this standpoint, imposition of feedlot runoff guidelines will not have a significant effect on fed beef production. Small lots, operated mostly by farmer-feeders may face costs significantly higher than these.

Cost vs. Pollution Control Achieved

The required investment and simmulated performance of 19 systems not capable of meeting the 1983 EPA guidelines were compared. The design parameters of the systems represented 0, 5, 10, . . . , 95% of the pump rate and storage capacity required to meet the 1983 guidelines for a 100 acre feedlot at Pendleton, Oregon. Costs were generated with the cost estimating model. Performance was simmulated with a computerized watershed model developed by Wensink and Miner (1975). Performance was measured as the % of total runoff the system would have contained over the period 1914-1971.

At this site, the estimated investment for a system to meet the 1983 guidelines is $2.34 per head of capacity. The resulting data indicate that relaxing guidelines would result in significant cost savings with only minor increases in runoff. A 5% increase in runoff was accompanied by a 25% reduction in required investment. By allowing 10% of the total runoff to escape, costs were reduced by 40%. With every increase in pollution controlled, the amount controlled per dollar spent decreases.

BIBLIOGRAPHY

1. Arrow, K. J. 1963. Social Choice and Individual Values. 2nd Edition. Wiley Press, New York.

2. Bressler, R. B. Jr. 1945. Research Determination of Economies of Scale. Journal of Farm Economics 27:526-539.

3. Coase, R. H. 1960. The Problem of Social Cost. Journal of Law and Economics 3:1-44.

4. Development Planning and Research Consultants, Inc. 1974. Cost, Capabilities, and Economic Impacts of Water Pollution Controls of Feedlot Industry. National Commission on Water Quality, Washington, D.C.

5. Dorfman, R., H. Jacoby, et al. 1971. The Economics of Water Supply and Quality. Harvard University Press, Cambridge, Massachusetts

6. Erdman, H.E. 1944. Interpretation of Variation in Cost Data for a Group of Individual Farms. Journal of Farm Economics 26:388-391.

7. Ferguson, C.E. and J.P. Gould. 1975. Microeconomic Theory. Richard D. Erwin, Inc. Homewood, Illinois.

8. Gee, K.C. 1976. Waste Management Practices of Western Feedlots. Economic Research Service, United States Department of Agriculture. Fort Collins, Colorado.

9. Gee, K.C. 1977. Costs of Producing Fed Beef in Commercial Feedlots. Economic Research Service, United States Department of Agriculture. Fort Collins, Colorado.

10. Gossett, D. L. and G. S. Willett. 1976. The Cost of Owning and Operating Sprinkler Irrigation Systems in the Columbia Basin. EM2760. Cooperative Extension Service, Washington State University.

11. Haynes, W. W. and W.R. Henry. 1974. Managerial Economics, Analysis and Cases. Business Publications, Inc., Dallas, Texas.

12. Henderson, J.M. and R.E. Quandt. 1975. Microeconomic Theory, A Mathematical Approach. McGraw-Hill Book Company. New York.

13. Heady, E.O. 1952. Economics of Agricultural Production and Resource Use. Prentice-Hall. New York.

14. Johnson, J.B., G.A. Davis, J.R. Martin and K.C. Gee. 1975. Economic Impacts of Controlling Surface Water Runoff from Fed-Beef Production Facilities. Agricultural Economic Report No. 292. Economic Research Service, United States Department of Agriculture. Washington, D.C.

15. Klocke, N.L. 1976. A Method to Evaluate the Cost-Effectiveness of Open Beef Feedlot Runoff Control Systems. Unpublished Master's Thesis. Department of Civil Engineering, University of Illinois.

16. Kneese, A.V. 1964. The Economics of Regional Water Control. Johns Hopkins Press. Baltimore, Maryland.

17. Kneese, A.V., R.U. Ayres, and R.C. D'Arge. 1970. Economics and the Environment A Materials Balance Approach. Resources for the Future, Inc. Washington, D.C.

18. Kneese, A.V. and C.L. Schultze. 1975. Pollution, Prices, and Public Policy. Brookings Institute, Washington, D.C.

19. Koelliker, J.K., H.L. Manges and R.I. Lipper. 1975. Modeling the Performance of Feedlot Runoff Control Facilities. Transactions of the ASAE 18(6):1118-1121.

20. Larsen, C.L., L.G. James, P.R. Goodrich and J.A. Bosch. 1974. Performance of Feedlot Runoff Control Systems in Minnesota. ASAE Paper No. 74-4913. ASAE. St. Joesph, Michigan.

21. Loehr, R.C. 1974. Agricultural Waste Management, Problems, Processes, and Approaches. McGraw-Hill Book Company. New York.

22. Maler, K.G. 1974. Environmental Economics: A Theoretical Inquiry. Johns Hopkins University Press. Baltimore, Maryland.

23. Miner, J.R. and F.T. Smith, Editors. 1975. Livestock Waste Management with Pollution Control. North Central Research Publication No. 222. Midwest Plan Service. Iowa State University.

24. Miner, J.R., R.B. Wensink and R.M. McDowell. 1977. Design and Cost of Feedlot Runoff Control Facilities. Grant No. R-803819-01-0. Prepared for Office of Research and Development, U.S. Environmental Protection Agency. Washington, D.C.

25. Pair, C.H., Ed. 1975. Sprinkler Irrigation, 4th Edition. Sprinkler Irrigation Association. Washington, D.C.

26. Randall, A. 1972. Market Solutions to Externality Problems. American Journal of Agricultural Economics 54:175-183.

27. Shuyler, L.R., D.M. Farmer, R.D. Kreis and M.E. Hula. 1973. Environment Protecting Concepts of Beef Cattle Feedlot Wastes Management. Office of Research and Development, U.S. Environmental Protection Agency. Corvallis, Oregon.

28. Stigler, J.G. 1958. The Economics of Scale. The Journal of Law and Economics. October 1958:57-71.

29. Stollsteimer, J.R., R.G. Bressler and J.N. Bolles. 1961. Cost Functions from Cross-sectional Data: Facts or Fantasy? Agricultural Economics Research 13:78-89.

30. Sweeten, J.M. 1976. Dilution of Feedlot Runoff. MP-1297. Texas Agricultural Extension Service. College Station, Texas.

31. USDA. 1976. Implications of EPA Proposed Regulations of November 20, 1975 for the Animal Feeding Industries. Prepared Under the Direction of the USDA Animal Waste Subcommittee. United States Department of Agriculture. Washington, D.C.

32. Wensink, R.B. and J.R. Miner. 1975. A Model to Predict the Performance of Feedlot Runoff Control Facilities at Specific Oregon Locations. Transactions of the ASAE 18(6):1141-1145, 1150.

33. Wensink, R.B. and J.R. Miner. 1977. Modeling the Effects of Management Alternatives on the Design of Feedlot Runoff Control Facilities. TRANSACTIONS of the ASAE 20:138-144.

APPENDICES

APPENDIX A

Supporting Tables

Table 1. Cost parameters used in model to generate output data.

Fortran Variable Name	Item	Estimated Value ($)
Cost A	Cost/yd^3 excavated	0.50
Cost B	Per ft cost of constructing diversion ditch	0.25
Cost C	Land cost per acre	750.00
Cost D	40' section of hand move irrig. pipe, w/sprinkler	45.00
Cost E	Cost of 1,320' side roll lateral	3,800.00
Cost F	Big gun w/capacity $<$ 500 gpm	400.00
Cost G	Big gun w/capacity $>$ 500 gpm	700.00
Cost H	Cost of complete traveling big gun	15,450.00
Cost I	Wire fence (per ft)	0.60
Cost J	Cost of seeding earthworks per $ value of earthworks	0.01
Cost K	Per foot cost of screen check dams	3.00
Cosk L	Insurance cost/$100 insured value	0.60
Cost M	Cost per kilowatt hour	0.0308
Cost N	Hourly wage rate for irrig. labor	3.50

Table 2. Components costs of continuously moving big guns.[a]

Component	Capacity, 500 gpm ($)	Capacity, 500-1, 000 gpm ($)
Traveling unit	2, 798	2, 798
Waste drive unit	96	96
Hose reel	1, 654	1, 654
Flexible hose	4, 607	4, 831
Hose couplings	120	136
Sprinkler	400	700
Total	9, 674	10, 188

[a]Source: Mitchell Irrigation Company.

Table 3. Calculation of present value of traveling big gun and necessary hose replacements.

End of Year	Item	Cost ($)	P. V. Factor[a]	P. V. of Cost ($)
0[b]	Traveler	10, 000[c]	1	10, 000
3[d]	Hose	4, 700[e]	0.638	3, 210
6[d]	Hose	4, 700	0.476	2, 237
Present value of system with two hoses				15, 447

[a]Present value factors are for a discount rate of 10%. From Agricultural Finance, Sixth Edition, by A. G. Nelson, W. F. Lee, and W. M. Murray, Iowa State University Press, 1973.

[b]Discounting convention refers to the beginning of the discounting period as the end of year zero.

[c]Average investment cost for traveling big gun (see Table 2 of the Appendix) is $9, 931. $10, 000 was used as the average price.

[d]Average lifetime of hose is estimated at three years. Replacement is assumed to be required at the ends of years 3 and 6 of the ten year total equipment lifetime.

[e]Average price of the flexible hose is $4, 719. A value of $4, 700 was used for expediency (see Appendix A, Table 2 for values).

Table 4. Specifications of pumps for hand move and side roll systems.

Discharge Capacity (gpm)	Pump Size (hp)	Cost ($)
50	5	1, 400
100	7	1, 600
200	10	1, 450
300	15	1, 650
400	20	1, 900
500	25	2, 100
600	30	2, 550
800	43	2, 900
1, 000	50	3, 300
1, 200	60	4, 000
1, 400	75	6, 400

Table 5. Specifications of pumps for stationary and traveling big gun systems.

Discharge Capacity (gpm)	Pump Size (hp)	Cost ($)
100	15	1, 400
150	20	1, 840
300	30	2, 280
450	40	2, 700
600	60	3, 280
850	75	3, 160
1, 150	100	6, 520

Table 6. Pump component costs.[a]

Item	Pump Size 5 hp	Pump Size 75 hp
Control panel[b]	$ 50	$ 512
Switch[b]	170	1,475
Electrical work	200	200
Install	60	120
Suction discharge assembly[b]	250	890
Subtotal	$ 730	$3,197
Pump	700	3,200
Total	$1,430	$6,397

[a]Source: Moore-Rane Manufacturing Company, Corvallis, Oregon.

[b]Marvin N. Shearer, Department of Agricultural Engineering, Oregon State University, Corvallis, Oregon.

Table 7. Aluminum mainline sizes, capacities[a] and costs.

Capacity (gpm)	Diameter (inches)	Cost ($/100 feet)
50	2	55
100	3	72
200	4	94
300	5	125
400	6	170
800	8	263
1,200	10	410

[a]Capacities based on gpm discharges with velocity in pipe at approximately five feet per second. Source: Buchner Irrigation Company. Fresno, California.

Table 8. "Big gun" nozzles: discharge rates, wetted radii, and application rates at 100 psi operating pressure.

Discharge Rate[a] (gpm)	Wetted Radius[a] (feet)	Application Rate (in/hr)
143	150	.19
185	160	.22
235	170	.25
290	180	.27
355	190	.30
425	200	.33
500	207	.36
575	232	.32
660	240	.35
775	250	.38
900	260	.41

[a] Source: Nelson Big Gun product literature, Nelson Irrigation Company.

APPENDIX B

Cost Estimating Model

```
      PROGRAM CONCOST
C                       CATTLE FEEDLOT RUNOFF CONTROL
C                          COST ESTIMATING MODEL
C
C
C                  VARIABLES      NOTATION AND EXPLANATION
C
C
      NGPMP   DISCHARGE CAPACITY OF PUMPS AVAILABLE FOR HAND MOVE
C             AND SIDE ROLL IRRIGATION SYSTEMS
C     NGPMP   DISCHARGE CAPACITY OF PUMPS FOR USE WITH HAND MOVE AND
C             SIDE ROLL IRRIGATION SYSTEMS
C     NCOSTP  COST OF PUMPS FOR USE WITH HAND MOVE AND SIDE ROLL SYSTEMS
C     NHPP    HORSEPOWER RATING OF PUMPS USED WITH HAND MOVE AND
C             SIDE ROLL SYSTEMS
C     MGPM    MAXIMUM CAPACITY OF MAINLINES
C     MCPF    COST PER 100 FEET OF MAINLINE
C
C     MSIZE   DIAMETER OF MAINLINE
C     KGPMP   DISCHARGE CAPACITY OF PUMPS FOR USE WITH STATIONARY AND
C             MOVING BIG GUN SYSTEMS
C     KCOSTP  COST OF PUMPS USED WITH STATIONARY AND MOVING BIG GUNS
C     KHPP    HORSEPOWER RATING OF PUMPS USED WITH STATIONARY AND MOVING
C             BIG GUN SYSTEMS
C     LASB    LAND AREA OCCUPIED BY SETTLING BASIN
C     L       LENGTH OF RETENTION POND AT FREEBOARD LEVEL
C     LADIV   LAND AREA OCCUPIED BY CLEAN WATER DIVERSION
C     LARPAP  LAND OCCUPIED BY RETENTION POND AND PERIMETER
C     LATOT   LAND AREA OCCUPIED BY TOTAL FACILITIES
C     MAXDA   MAXIMUM DAILY APPLICATION OF WASTE PER ACRE PER DAY
C     DISP    DISPOSAL POLICY IDENTIFIER
C     ROVOL   REQUIRED STORAGE VOLUME PER FEEDLOT ACRE
C     DPRATE  DESIGN PUMPING RATE PER FEEDLOT ACRE
C     PDAYS   AVERAGE PUMPING DAYS PER YEAR
```

```
C       ADP     DISPOSAL PLOT ACREAGE REQUIRED PER FEEDLOT ACRE
C       ADS     DISPOSAL SITE ACREAGE REQUIRED PER FEEDLOT ACRE
C       FLAREA  FEEDLOT AREA IN ACRES
C       MANPOL  MANAGEMENT POLICY IDENTIFIER
C       COSTA   EXCAVATION CHARGE: $/CUBIC YARD
C       COSTB   DIVERSION DITCH COST: $/LINEAL FOOT
C       KOSTC   LAND COST: $/ACRE
C       COSTD   COST OF 40 FOOT SECTION OF ALUMINUM HAND
C               MOVE IRRIGATION PIPE
C       COSTE   COST OF 1320 FOOT SIDE ROLL IRRIGATION LATERAL
C       KOSTF   COST OF BIG GUN IRRIGATION SPRINKLER WITH CAPACITY
C               LESS THAN 500 GALLONS PER MINUTE
C       KOSTG   COST OF BIG GUN IRRIGATION SPRINKLER WITH CAPACITY
C               GREATER THAN 500 GALLONS PER MINUTE
C       KOSTH   COST OF TRAVELLING BIG GUN SYSTEM, COMPLETE WITH HOSE
C       COSTI   FENCING COST: $/LINEAL FOOT
C       COSTJ   SEEDING COST COEFFICIENT
C       COSTK   COST OF SCREEN DAMS FOR SETTLING BASIN:
C               $ PER LINEAL FOOT
C       COSTL   INSURANCE COST: $/ $ INSURED VALUE
C       COSTM   ELECTRICITY COST: $/ KWH
C       COSTN   HOURLY WAGE RATE FOR IRRIGATION LABOR
C       AMORT   AMORTIZATION FACTOR
C       TRATE   TAX RATE PER ONE DOLLAR OF ASSESED VALUE
C       XADP    TOTAL DISPOSAL PLOT ACREAGE
C       XADS    TOTAL DISPOSAL SITE ACREAGE
C       XPRATE  TOTAL PUMPING RATE REQUIRED PER DAY
C       PVOL    TOTAL VOLUME PUMPED PER YEAR
C       SBVOL   SETTLING BASIN VOLUME IN CUBIC YARDS
C       SBCOST  COST OF EXCAVATING SETTLING BASIN
C       CDIV    COST OF EXCAVATING CLEAN WATER DIVERSION
C       HLDVOL  TOTAL REQUIRED HOLDING VOLUME IN CUBIC YARDS
C       EXVOL   VOLUME TO BE EXCAVATED TO PROVIDE POND WITH CAPACITY OF
C               HLDVOL AND PROVIDING ONE FOOT OF FREEBOARD
C       RPCOST  COST OF EXCAVATING THE RETENTION POND
C       EXCOST  TOTAL COST OF ALL EXCAVATION WORK
C       KLASB   COST OF LAND OCCUPIED BY SETTLING BASIN
```

```
C     KLADIV COST OF LAND OCCUPIED BY CLEAN WATER DIVERSION
C     KLARPAP COST OF LAND OCCUPIED BY RETENTION POND AND PERIMETER
C     KLADIS COST OF LAND AREA OCCUPIED BY DISPOSAL SITE
C             *WHEN APPROPRIATE**
C     LCTOT  TOTAL COST OF LAND CHARGED TO RUNOFF CONTROL SYSTEM
C     TSET   HOURS PER IRRIGATION SET
C     LCHM   COST OF LETERALS FOR HAND MOVE IRRIGATION SYSTEM
C     LCSR   COST OF LATERALS FOR SIDE ROLL IRRIGATION SYSTEM
C     GPM    PUMPING RATE FOR SIDE ROLL, HAND MOVE, AND BIG GUN SYSTEMS
C     IGPM   INTEGER VALUE OF VARIABLE "GPM"
C     NPCNT  COUNTER FOR PUMP SELECTOR LOOP SELECTING PUMPS FOR
C            HAND MOVE AND SIDE ROLL SYSTEMS
C     IPUMP  DO LOOP FOR HAND MOVE AND SIDE ROLL PUMP SELECTION
C     NPCNT  TOTAL NUMBER OF PUMPS REQUIRED FOR HAND MOVE AND SIDE
C            ROLL IRRIGATION SYSTEMS
C     ITPCST TOTAL COST OF PUMPS FOR THE HAND MOVE AND SIDE ROLL SYSTEMS
C     JGPM   REQUIRED PUMPING RATE FOR SIDE ROLL SYSTEM
C     JPCNT  NUMBER OF PUMPS REQUIRED FOR SIDE ROLL SYSTEM
C     JHPP   HORSEPOWER RATING OF PUMP(S) FOR SIDE ROLL SYSTEM
C     JCOSTP COST OF INDIVIDUAL PUMP(S) SELECTED FOR SIDE ROLL SYSTEM
C     JGPMP  DISCHARGE RATE OF INDIVIDUAL PUMPS SELECTED FOR SIDE ROLL
C     JTPCST TOTAL COST OF PUMPS FOR SIDE ROLL SYSTEM
C     LMAINA LENGTH OF MAINLINE REQD. FOR HAND MOVE AND
C            SIDE ROLL SYSTEMS
C     KOUNTA COUNTER FOR MAINLINE SELECTION LOOP; NUMBER OF MAINS REQD.
C     IMAIN  DO LOOP FOR MAINLINE SELECTION FOR HAND MOVE AND
C            SIDE ROLL SYSTEMS
C     ICMA   COST OF MAINLINE FOR HAND MOVE AND SIDE ROLL SYSTEMS
C     IGPMT  TOTAL SYSTEM DISCHARGE RATE FOR HAND MOVE AND SIDE ROLL
C            IRRIGATION SYSTEMS
C     JGPMT  TOTAL DISCHARGE RATE FOR SIDE ROLL IRRIGATION SYSTEMS
C     JKOUNT COUNTER FOR SIDE ROLL SYSTEM MAINLINE SELECTION LOOP
C     JGPM   MAINLINE CAPACITY FOR SIDE ROLL SYSTEM
C     JCPF   COST PER 100 FEFT OF MAINLINE FOR SIDE ROLL SYSTEM
C     JSIZE  DIAMETER OF MAINLINE FOR SIDE ROLL SYSTEM
C     JCMA   TOTAL COST OF MAINLINE FOR SIDE ROLL SYSTEM
C     JMAIN  LENGTH OF MAINLINE REQD. FOR SIDE ROLL SYSTEM
```

```
C     ITCHM  TOTAL COST OF HAND MOVE IRRIGATION SYSTEM
C     ITCSR  TOTAL COST OF SIDE ROLL IRRIGATION SYSTEM
C     GPMBG  PUMPING RATE FOR BIG GUN SYSTEMS IN GALLONS PER MINUTE
C     NBG    NUMBER OF BIG GUNS REQUIRED FOR SYSTEM
C     IGPMBG DISCHARGE PER BIG GUN IN GALLONS PER MINUTE
C     ITCBG  TOTAL COST OF BIG GUNS
C     KGPMBG PUMP RATE FOR BIG GUN SYSTEM: FOR PUMP SELECTOR LOOP
C     KPCNT  COUNTER FOR BIG GUN SYSTEM PUMP SELECTOR LOOP
C     KPUMP  DO LOOP FOR BIG GUN SYSTEM PUMP SELECTION
C     KTPCST TOTAL COST OF PUMP(S) FOR BIG GUN SYSTEM
C     KHPPL  HORSEPOWER RATING OF INDIVIDUAL PUMP(S) FOR
C            BIG GUN IRRIGATION SYSTEM
C     MSIZEL DIAMETER OF MIANLINE REQD. FOR BIG GUN SYSTEM
C     MCPFL  COST PER 100 FEET OF MAINLINE FOR BIG GUN SYSTEM
C     KGPMT  TOTAL DISCHARGE CAPACITY FOR BIG GUN SYSTEM
C     KMGPM  MAINLINE CAPACITY REQD. FOR BIG GUN SYSTEM
C     LMAINB LENGTH OF MAINLINE REQD. FOR BIG GUN SYSTEM
C     KOUNTB COUNTER FOR BIG GUN SYSTEM MAINLINE SELECTOR: TOTAL
C            NUMBER OF MAINLINES REQUIRED
C     KMAIN  DO LOOP FOR MAINLINE SELECTION FOR BIG GUN SYSTEM
C     ICMB   TOTAL COST OF MAINLINE FOR BIG GUN SYSTEM
C     ITCBGS TOTAL COST OF BIG GUN SYSTEM
C     MBGGPM PUMPING RATE FOR MOVING BIG GUN SYSTEM
C     CMBG   REAL NUMBER VALUE OF "MBGGPM"
C     NMBG   NUMBER OF MOVING BIG GUNS NECESSARY
C     ICMB   TOTAL COST OF MOVING BIG GUNS
C     LGPM   TOTAL DISCHARGE CAPACITY FOR MOVING BIG GUN SYSTEM:
C            USED IN PUMP SELECTOR LOOP
C     LPCNT  COUNTER FOR PUMP SELECTOR LOOP FOR MOVING BIG GUN SYSTEM:
C            NUMBER OF PUMPS REQUIRED FOR MOVING BIG GUN SYSTEM
C     LPUMP  DO LOOP FOR PUMP SELECTION FOR MOVING BIG GUN SYSTEM
C     LTPCST TOTAL COST OF PUMPS FOR MOVING BIG SYSTEM
C     LMAINC LENGTH OF MAINLINE REQUIRED FOR MOVING BIG GUN SYSTEM (FT.)
C     KOUNTC COUNTER FOR MAINLINE SELECTOR FOR MOVING BIG GUN SYSTEM
C     LMAIN  DO LOOP FOR MAINLINE SELECTION FOR MOVING BIG GUN SYSTEM
C     LMGPM  TOTAL DISCHARGE FROM MAINLINE FOR MOVING BIG GUN SYSTEM:
C            IN GALLONS PER MINUTE
C     ICMC   TOTAL COST OF MAINLINE FOR MOVING BIG GUN SYSTEM
```

```
C       ITCMB   TOTAL COST OF MOVING BIG GUN SYSTEMS
C       CFENCE  TOTAL COST OF FENCING
C       CERP    TOTAL COST OF SEEDING EARTHWORKS TO GRASS
C       CDAMS   TOTAL COST OF SCREEN DAMS FOR SETTLING BASIN
C       CENG    TOTAL COST OF ENGINEERING AND SURVEYING
C       CMISC   TOTAL MISCELLANEOUS COST
C       ICOST   TOTAL INVESTMENT EXCLUSIVE OF IRRIGATION SYSTEM
C               FOR HAND MOVE AND BIG GUN SYSTEMS
C       JCOST   TOTAL INVESTMENT EXCLUSIVE OF IRRIGATION SYSTEM
C               FOR SIDE ROLL SYSTEM
C       LCOST   TOTAL INVESTMENT EXCLUSIVE OF IRRIGATION SYSTEM
C               FOR MOVING BIG GUN SYSTEM
C       TCOSTA  TOTAL COST FOR RUNOFF CONTROL FACILITIES USING
C               HAND MOVE IRRIGATION SYSTEM
C       TCOSTB  TOTAL COST FOR RUNOFF CONTROL FACILITIES USING
C               SIDE ROLL IRRIGATION SYSTEM
C       TCOSTC  TOTAL COST FOR RUNOFF CONTROL FACILITIES USING
C               BIG GUN IRRIGATION SYSTEMS
C       TCOSTD  TOTAL COST OF RUNOFF CONTROL FACILITIES USING
C               MOVING BIG GUN IRRIGATION SYSTEMS
C       ACDIEN  ANNUAL COST OF DEPRECIATION AND INTEREST FOR
C               NON-IRRIGATION ITEMS
C       ACDIHM  ANNUAL COST OF DEPRECIATION AND INTEREST FOR
C               HAND MOVE IRRIGATION SYSTEM
C       ACDISR  ANNUAL COST OF DEPRECIATION AND INTEREST FOR
C               SIDE ROLL SYSTEM
C       ACDIBG  ANNUAL COST OF DEPRECIATION AND INTEREST FOR
C               BIG GUN SYSTEM
C       ACDITG  ANNUAL COST OF DEPRECIATION AND INTEREST FOR
C               MOVING BIG GUN SYSTEM
C       ACTEN   ANNUAL TAX ON NON-IRRIGATION ITEMS
C       ACTHM   ANNUAL TAX ON HAND MOVE IRRIGATION SYSTEM
C       ACTSR   ANNUAL TAX ON SIDE ROLL IRRIGATION SYSTEM
C       ACTBG   ANNUAL TAX ON BIG GUN IRRIGATION SYSTEM
C       ACTMBG  ANNUAL TAX ON MOVING BIG GUN IRRIGATION SYSTEM
C       ACMRHM  ANNUAL COST OF MAINT. AND REPAIR ON HAND MOVE SYSTEM
C       ACMRSR  ANNUAL COST OF MAINT. AND REPAIR ON SIDE ROLL SYSTEM
C       ACMRBG  ANNUAL COST OF MAINT. AND REPAIR ON BIG GUN SYSTEM
```

```
C       ACMRTG ANNUAL COST OF MAINT. AND REPAIR ON MOVING BIG GUN SYSTEM
C       ACMREW ANNUAL COST OF MAINT. AND REPAIR ON EARTHWORKS
C       ACINHM ANNUAL COST OF INSURANCE FOR HAND MOVE SYSTEM
C       ACINSR ANNUAL COST OF INSURANCE FOR SIDE ROLL SYSTEMS
C       ACINBG ANNUAL COST OF INSURANCE FOR BIG GUN SYSTEM
C       ACINTG ANNUAL COST OF INSURANCE FOR MOVING BIG GUN SYSTEM
C       ELECHM ANNUAL COST OF ELECTRICITY FOR HAND MOVE SYSTEM
C       ELECSR ANNUAL COST OF ELECTRICITY FOR SIDE ROLL SYSTEM
C       ELECBG ANNUAL COST OF ELECTRICITY FOR BIG GUN SYSTEM
C       ELECTG ANNUAL COST OF ELECTRICITY FOR MOVING BIG GUN SYSTEM
C       CLABHM ANNUAL COST OF LABOR FOR HAND MOVE SYSTEM
C       CLABSR ANNUAL COST OF LABOR FOR SIDE ROLL SYSTEM
C       CLABBG ANNUAL COST OF LABOR FOR BIG GUN SYSTEM
C       CLABTG ANNUAL COST OF LABOR FOR MOVING BIG GUN SYSTEM
C       TACHM  TOTAL ANNUAL COST OF OPERATING HAND MOVE SYSTEM
C       TACSR  TOTAL ANNUAL COST OF OPERATING SIDE ROLL SYSTEM
C       TACBG  TOTAL ANNUAL COST OF OPERATING BIG GUN SYTEM
C       TACTG  TOTAL ANNUAL COST OF OPERATING MOVING BIG GUN SYSTEM
C       TACEW  TOTAL ANNUAL COST OF EARTHWORKS FOR RUNOFF CONTROL SYSTEMS
C              USING HAND MOVE AND BIG GUN SYSTEMS
C       TACEWJ TOTAL ANNUAL COST OF EARTHWORKS FOR RUNOFF CONTROL SYSTEMS
C              USING THE SIDE ROLL IRRIGATION SYSTEM
C       TACEWL TOTAL ANNUAL COST OF EARTHWORKS FOR RUNOFF CONTROL SYSTEMS
C              USING THE MOVING BIG GUN IRRIGATION SYSTEM
C       TACA   TOTAL ANNUAL COST OF FACILITIES USING HAND MOVE SYSTEM
C       TACB   TOTAL ANNUAL COST OF FACILITIES USING SIDE ROLL SYSTEM
C       TACC   TOTAL ANNUAL COST OF FACILITIES USING BIG GUN SYSTEM
C       TACD   TOTAL ANNUAL COST OF FACILITIES USING
C              MOVING BIG GUN SYSTEM
C       CCAPA  ANNUAL COST PER HEAD OF CAPACITY USING HAND MOVE SYSTEM
C       CCAPB  ANNUAL COST PER HEAD OF CAPACITY USING SIDE ROLL SYSTEM
C       CCAPC  ANNUAL COST PER HEAD OF CAPACITY USING BIG GUN SYSTEM
C       CCAPD  ANNUAL COST PER HEAD OF CAPACITY USING MOVING BIG GUN
C       CHEADA ANNUAL COST PER HEAD USING HAND MOVE SYSTEM
C       CHEADB ANNUAL COST PER HEAD USING SIDE ROLL SYSTEM
C       CHEADC ANNUAL COST PER HEAD USING BIG GUN SYSTEM
C       CHEADD ANNUAL COST PER HEAD USING MOVING BIG GUN SYSTEM
C       TICAPA TOTAL INVESTMENT PER HEAD WITH HAND MOVE SYSTEM
C       TICAPB TOTAL INVESTMENT PER HEAD WITH SIDE ROLL SYSTEM
```

```
C     TICAPC TOTAL INVESTMFNT PFR HEAD WITH BIG GUN SYSTEM
C     TICAPC TOTAL INVESTMENT PER HEAD WITH MOVING BIG GUN SYSTEM
C     XMIN   MINIMUM YEARLY LABOR COST FOR ANY SYSTEM
C
      DIMENSION NGPMP(11),NCOSTP(11),NHPP(11)
      DATA(NGPMP=50,100,200,300,400,500,600,900,1000,1200,1400)
      DATA(NCOSTP=1400,1600,1450,1650,1900,2100,2550,2900,3300,4000,
     *6400)
      DATA(NHPP=5,7,10,15,20,25,30,43,50,60,75)
C
      DIMENSION MGPM(7),MCPF(7),MSIZE(7)
      DATA(MGPM=100,200,300,400,600,1200,2000)
      DATA(MCPF=55,72,94,125,170,263,410)
      DATA(MSIZE=2,3,4,5,6,8,10)
C
      DIMENSION KGPMP(7),KCOSTP(7),KHPP(7)
      DATA(KGPMP=100,150,300,450,600,850,1150)
      DATA(KCOSTP=1400,1840,2280,2700,3200,3160,6520)
      DATA(KHPP=15,20,30,40,60,75,100)
C
C
C
      REAL LASB,L,LADIV,LARPAP,LATOT,MAXDA
C
C
C     * MANAGEMENT DISPOSAL ALTERNATIVE IDENTIFIER *
C        NUTRIENT UTIL. : DISP=2
C        STRICT WASTE DIDPOSAL :  DISP=1.
C
C
C
      WRITE(61,1000)
 1000 FORMAT(* ENTER DESIGN VARIABLES--STORAGE VOL., PUMPING RATE,*/
     ** PUMPING DAYS, DISPOSAL PLOT ACREAGE, DISPOSAL SITE ACREAGE,*,
     ** DISPOSAL POLICY IDENTIFIER, MAXIMUM DAILY WASTE APPLICATION*,
     ** , FEEDLOT AREA*,)
```

```
C
      READ(60,1010)ROVOL,OPRATE,PDAYS,ADP,ADS,DISF,MAXDA,FLAREA
 1010 FORMAT(F9.3)
C
      WRITE(61,1020)
 1020 FORMAT(* ENTER MANAGEMENT POLICY*)
      READ(60,1030)MANPOL
 1030 FORMAT(I1)
C
C             INPUT COST VARIABLES
C
      COSTA=.5
      COSTB=.25
      KOSTC=750
      COSTD=45.
      COSTE=3800.
      KOSTF=400
      KOSTG=700
      KOSTH=15450
      COSTI=.60
      COSTJ=.01
      COSTK=4.15
      COSTL=.006
      COSTM=.0309
      COSTN=3.5
      AMORT=.16275
      TRATE=.0093
C
C           MAXIMUM DAILY APPLICATION OF WASTE IN ACRE-INCHES PER ACRE
C
      XADP=FLAREA*ADP
      XADS=FLAREA*ADS
      XPRATE=FLAREA*OPRATE
      PVOL=XPRATE*PDAYS
C
C
C
```

```
C                                   CALCULATION OF INVESTMENT COST
C
C
C
C             **CALCULATE COST OF CONSTRUCTING EARTHWORKS**
C
C
C
C             SETTLING BASIN
C
C
      SBVOL=FLAREA*134.4
      SBCOST=SBVOL*COSTA
C
C
C             CLEAN WATER DIVERSION DITCH/TERRACE
C
C
      CDIV=SQRT(FLAREA*43560.)*3.*COSTB
C
C
C             RETENTION RESIVOIR
C
C
      HLDVOL=ROVOL*FLAREA*3630.
      L=32.+SQRT((HLDVOL-3654.)/14.)
      EXVOL=.555*(L*L-60.*L+1200.)
      IF(EXVOL.LT.600.) GO TO 1040
      CONTINUE
      GO TO 1050
 1040 EXVOL=600.
 1050 RPCOST=EXVOL*COSTA
C
C
C             COMPLTE TOTAL COST FOR EARTHWORKS
C
C
      EWCOST=SBCOST+CDIV+RPCOST
```

```
C
C
C         **CALCULATE COST LAND REQUIRED FOR TOTAL FACILITIES**
C
C
C                LAND AREA FOR SETTLING BASIN
C
C
      LASB=(12.+SQRT(144.+3621.*FLAREA/2.))**2/87120.
C
C
C
      KLASB=LASB*KOSTC
C
C                LAND AREA FOR CLEAN WATER DIVERSION DITCH/TERRACE
C
C
      LADIV=24.*SQRT(FLAREA*43560.)/43560.
      KLADIV=LADIV*KOSTC
C
C
C                LAND AREA FOR RETENTION RESIVOIR AND PERIMETER
C
C
      LARPAP=(L*L+202.*L+10201.)/43560.
      KLARP=LARPAP*KOSTC
C
C
C                LAND FOR DISPOSAL
C
      IF(DISP.EQ.1.) GO TO 1100
      CONTINUE
      KLADIS=0
      GO TO 1110
C
 1100 KLADIS=XADS*KOSTC
C
C
```

```
C
C                 CALCULATE TOTAL LAND COST
C
C
 1110 LATOT=LARPAP+LADIV+LASB
      LCTOT=LATOT*KOSTC+KLADIS
C
C
C              IRRIGATION EQUIPMENT
C               CALCULATE HOURS PER SET
C
      TSET=MAXDA/.33
C
C
      IF(TSET.GT.10.) GOTO 1130
C
C                 COST OF LATERALS FOR HM& & SR SYSTEMS
C                        WHEN TSET<10 HOURS
C
 1120 LCHM=IFIX(9.075*COSTO*XADP)
      LCSR=IFIX(0.278*COSTE*XADP)
      GO TO 1140
C
C
C                 COST OF LATERALS FOR HM & SR SYTEMS
C                        WHEN TSET>10 HOURS
C
C
 1130 LCHM=IFIX(18.15*COSTO*XADP)
      LCSR=IFIX(.566*COSTE*XADP)
C
      GO TO 1150
C
C                CALCULATE HM & SR SYSTEM CAPACITY WHEN TSET<10 HOURS
C
 1140 GPM=226.3*XPRATE/TSET
      GO TO 1160
C
C                CALCULATE HM & SR SYSTEM CAPACITY WHEN TSET>10 HOURS
```

```
C
 1150 GPM=452.5*XPRATE/TSET
C
C
C
C               PUMPS FOR HM & SR SYTEMS
C
 1160 IGPM=IFIX(GPM)
      NPCNT=1
 1170 DO 1180 IPUMP=1,11
      IF(IGPM.LE.NGPMP(IPUMP)) GO TO 1190
 1180 CONTINUE
      NPCNT=NPCNT+1
      IGPM=GPM*(1.0/NPCNT)
      GO TO 1170
 1190 ITPCST=NPCNT*NCOSTP(IPUMP)
C
C          CREATION OF VARIABLES FOR SIDE ROLL DOCUMENTATION
C
      JGPM=IFIX(GPM)
      JPCNT=NPCNT
      JHPP=NHPP(IPUMP)
      JCOSTP=NCOSTP(IPUMP)
      JGPMP=NGPMP(IPUMP)
      JTPCST=ITPCST
C               CALCULATE COST OF MAINLINE FOR HM & SR SYSTEMS
C
      LMAINA=IFIX(SQRT(XADS*43560.)+300.)
      KOUNTA=1
 1200 DO 1210 IMAIN=1,7
      IF(JGPM.LE.NGPM(IMAIN)) GO TO 1220
 1210 CONTINUE
      KOUNTA=KOUNTA+1
      JGPM=GPM*(1.0/KOUNTA)
      GO TO 1200
C
 1220 ICMA=FLOAT(LMAINA)/100.*MCPF(IMAIN)*KOUNTA
```

```
C
      IGPMT=IFIX(GPM)
      JGPMT=IGPMT
C
C          CREATION OF VARIABLES FOR SIDE ROLL DOCUMENTATION
C
      JKOUNT=KOUNTA
      JMGPM=MGPM(IMAIN)
      JCPF=MCPF(IMAIN)
      JSIZE=MSIZE(IMAIN)
      JCMA=ICMA
      JMAIN=LMAINA
C
C                CALCULATE TOTAL COST OF HM + SR SYSTEMS
C
      ITCHM=LCHM+ICMA+ITPCST
      ITCSR=LCSR+ICMA+ITPCST
C
C             BIG GUN SYSTEM
C
      IF(TSET.GT.16.) GO TO 1240
C
C                CALCULATE BG SYSTEM CAPACITY WHEN TSET<16 HOURS
C
C
      GPMBG=226.28*XPRATE/TSET
      GO TO 1250
C
C                CALCULATE BG SYSTEM CAPACITY WHEN TSET>10 HOURS
C
 1240 GPMBG=452.55*XPRATE/TSET
C
C                CALCLLATE NUMBEP OF BIG GUNS REQUIRED
C
 1250 NBG=IFIX(GPMBG/1000.+1.)
      IBGGPM=GPMBG/NBG
C
      IF(IBGGPM.GT.499) GO TO 1260
```

```
C
C              CALCULATE COST OF BIG GUN(S)
C
      ITCBG=NBG*KOSTF
      GO TO 1270
C
 1260 ITCBG=NBG*KOSTG
C
C
C
C
C               PUMP SELECTOR FOR BG SYSTEM
C
 1270 KGPM=IFIX(GPMBG)
      KPCNT=1
 1280 DO 1290 KPUMP=1,7
      IF(KGPM.LE.KGPMP(KPUMP)) GO TO 1300
 1290 CONTINUE
      KPCNT=KPCNT+1
      KGPM=GPMBG*(1.0/KPCNT)
      GO TO 1280
C
 1300 KTPCST=KPCNT*KCOSTP(KPUMP)
      KHPPL=KHPP(LPGMP)
      MSIZEL=MSIZE(LMAIN)
      MCPFL=MCPF(LMAIN)
C
C
C
      KGPMT=KGPM*KPCNT
C
C           MAINLINE SELECTION FOR BG SYSTEMS
C
      KMGPM=KGPM*KPCNT
      LMAINB=300+IFIX((SQRT(XADS*43560.))*2.)
C
      KOUNTe=1
 1310 DO 1320 KMAIN=1,7
```

```
      IF(KMGPM.LE.MGPM(KMAIN)) GO TO 1340
 1320 CONTINUE
      KOUNTB=KOUNTB+1
      KMGPM=KGPMT*(1.0/KOUNTB)
      GO TO 1310
C
 1340 ICMB=FLOAT(LMAINB)/100.*MCPF(KMAIN)*KOUNTB
C
C
C
C                CALCULATE TOTAL COST OF BIG GUN SYSTEM
C
C
      ITCBGS=ITCBG+KTPCST+ICMB
C
C
C
C                CALCULATIONS FOR TRAVELING BIG GUN
C            TEST FOR MINIMUM PUMP RATE FOR TBG SYSTEM
C
      IF(XPRATE.LT.12.15) GO TO 1410
C

      MBGGPM=IFIX(XPRATE*20.57)
      CMBG=FLOAT(MBGGPM)
      NMBG=IFIX((MBG/1000.+1.0)
      ICMBG=NMBG*KOSTH
C
C                    PUMP SELECTION FOR TBG
C
      LGPM=MBGGPM
      LPCNT=1
 1350 DO 1360 LPUMP=1,7
      IF(LGPM.LE.KGPMP(LPUMP)) GO TO 1370
 1360 CONTINUE
      LPCNT=LPCNT+1
      LGPM=MBGGPM*(1.0/LPCNT)
      GO TO 1350
C
```

```
 1370 LTPCST=LPCNT*KCOSTP(LPUMP)
C
C
C                    MAINLINE SELECTION FOR TBG SYSTEM
C
      LMAINC=300+IFIX((XADS*43560.0)/1620.0)
      LMGPM=MBGGFM
C
      KOUNTC=1
 1380 DO 1390 LMAIN=1,7
      IF(LMGPM.LE.MGPM(LMAIN)) GO TO 1400
 1390 CONTINUE
      KOUNTC=KOUNTC+1
      LMGPM=MBGGFM*(1.0/KOUNTC)
      GO TO 1380
 1400 ICMC=FLOAT(LMAINC)/100.*MCPF(LMAIN)*KOUNTC
C
C
C              CALCLLATE TOTAL COST OF TRAVELING BIG GUN SYSTEM
C
      ITCMBG=ICMBG+LTPCST+ICMC
C
C
C             MISCELLANEOUS COSTS
C
C
C
C
C                       CALCULATE COST OF FENCING
C
C
 1410 CFENCE=(L+101.)*4.*COSTI
C
C
C
C                      CALCULATE COST OF EROSION CONTROL(SEEDING)
C
```

```
C
C
      CERP=ENCOST*COSTJ
C
C
C
C                   SETTLING BASIN CHECK DAMS
C
C
      CDAMS=(12.+SQRT(144.+(3621.*FLAREA)/2))*COSTK
C
C
C
C         COST OF ENGINEERING
C
      CENG=200.
C
C
C                   CALCULATE TOTAL MISCELANEOUS COST
C
      CMISC=CFENCE+CERP+CDAMS+CENG
C
C
C
C
      ICOST=ENCOST+LCTOT+CMISC
      JCOST=ICOST
      LCOST=ICOST
C
C
C        CALCULATE TOTAL INVESTMENT
C
      TCOSTA=ICOST+ITCHM
      TCOSTB=ICOST+ITCSR
      TCOSTC=ICOST+ITCBGS
      TCOSTD=ICOST+ITCMDG
C
```

```
C              CATTLE FEEDLOT RUNOFF RETENTION FACILITIES ANNUAL COSTS
C
C
C                                       VARIABLES AND NOTATION
C
C
C
C
C                                    COMPUTATION OF ANNUAL OPERATING COSTS
C
C
C         CALCULATE EQUIVALENT ANNUAL COST OF DEPRECIATION AND INTERSET
C
      ACDIEW=(EWCOST+CMISC+LCTOT)*AMORT
      ACDIHM=ITCHM*AMORT
      ACDISR=ITCSR*AMORT
      ACDIBG=ITCBGS*AMORT
      ACDITG=ITCMBG*AMORT
C
C
C
C
C
C                   COMPUTE ANNUAL TAX COST
C
      ACTEW=(EWCOST+CMISC+LCTOT)*TRATE
      ACTHM=ITCHM*TRATE*.5
      ACTSR=ITCSR*TRATE*.5
      ACTBG=ITCBGS*TRATE*.5
      ACTMBG=ITCMBG*TRATE*.5
C
C
C
C
C                   COMPUTE ANNUAL COST OF MAINTAINENCE AND REPAIR
C
C
C
```

```
      ACMRHM=.06*ITFCST+.02*LCHM+.02*ICMA
      ACMRSR=.06*ITFCST+.03*LCSR+.02*ICMA
      ACMRBG=.06*KTPCST+.02*ITCBG+.02*ICMB
      ACMRTG=.06*LTPCST+.03*ICMBG+.02*ICMC
      ACMREN=(ENCOST+CMISC)*.005
C
C
C
C
C                    COMPUTE ANNUAL COST OF INSURANCE
C
C
      ACINHM=COSTL*ITCHM*.5
      ACINSR=COSTL*ITCSR*.5
      ACINBG=COSTL*ITCBGS*.5
      ACINTG=COSTL*ITCMBG*.5
C
C
C
C                    COMPUTE ENERGY COSTS FOR PUMPING
C
      ELECHM=19.12*PVOL*COSTM
      ELECSR=19.12*PVOL*COSTM
      ELECBG=38.24*PVOL*COSTM
      ELECTG=38.24*PVOL*COSTM
C
C
C
C                    COMPUTE ANNUAL COST OF LABOR
C
C
C
      CLABHM=.633*XADP*PDAYS*COSTN
C
      IF(TSET.GT.10.) GO TO 1420
      CLABSR=.66*COSTN*PDAYS*IFIX(.278*XADP+1.)
      GO TO 1430
 1420 CLABSR=.33*COSTN*PDAYS*IFIX(XADP/1.8+1.0)
```

```
C
 1430 CLABBG=.52*XAOP*PDAYS*COSTN
      CLABTG=NMBG*PDAYS*COSTN
C
C
C        COMPUTE TOTAL ANNUAL COSTS OF IRRIGATION SYSTEMS
C
C
      TACHM=ACOIHM+ACTHM+ACMRHM+ACINHM+ELECHM+CLABHM
      TACSR=ACOISR+ACTSR+ACMRSR+ACINSR+ELECSR+CLABSR
      TACBG=ACOIBG+ACTBG+ACMRBG+ACINBG+ELECBG+CLABBG
      TACIG=ACOITG+ACTMBG+ACMRTG+ACINTG+ELECTG+CLABTG
C
C
      TACEW=ACOIEW+ACTEW+ACMREW
      TACEWJ=TACEW
      TACEWL=TACEW
C
C
C        COMPUTE TOTAL ANNUAL COSTS
C
      TACA=TACHM+TACEW
      TACB=TACSR+TACEW
      TACC=TACBG+TACEW
      TACD=TACIG+TACEW
C
      CCAPA=TACA/(FLAREA*200.)
      CCAPB=TACB/(FLAREA*200.)
      CCAPC=TACC/(FLAREA*200.)
      CCAPD=TACD/(FLAREA*200.)
C
      CHEADA=CCAPA/3.
      CHEADB=CCAPB/3.
      CHEADC=CCAPC/3.
      CHEADD=CCAPD/3.
C
C
C           CALCULATE INVESTMENT/HEAD OF CAPACITY
```

```
C
C
      TICAPA=TCOSTA/(FLAREA*200.)
      TICAPB=TCOSTB/(FLAREA*200.)
      TICAPC=TCOSTC/(FLAREA*200.)
      TICAPD=TCOSTD/(FLAREA*200.)
C
C        CHECK FOR MIN. OF 1 HR. LABOR PER DAY FOR HM, SR +BG SYSTEMS
      XMIN=COSTN*IFIX(PDAYS+1.)
      IF(CLABHM.LT.XMIN) CLABHM=XMIN
      IF(CLABSR.LT.XMIN) CLABSR=XMIN
      IF(CLABBG.LT.XMIN) CLABBG=XMIN
C
C        CHECK FOR MINIMUM DISPOSAL PLOT SIZE FOR SIDE ROLL SYSTEM
C            (SYSTEM NOT APPLICABLE UNLESS PLOT SIZE >-IS MIN. .1 ACRE)
C
      IF(XADP.GE.1.000) GO TO 1440
      ITCSR=0
      TACSR=0.
      LCSR=0
      JTPCST=0
      JGPMP=0
      JPCNT=0
      JCOSTP=0
      JHPP=0
      JKOUNT=0
      JHGPM=0
      JCMA=0
      JCPF=0
      JSIZE=0
      TCOSTB=0.
      ACDISR=0.
      ACTSR=0.
      ACMRSR=0.
      ACINSR=0.
      ELECSR=0.
      CLABSR=0.
      TACB=0.
```

```
      CCAP8=0.
      CHEAD8=0.
      TICAP8=0.
      JMAIN=0
      JGPMT=0
      TACENJ=0.
      JCOST=0
C
 1440 IF(XPRATE.GE.12.15) GO TO 2600
C
      ITCMBG=0
      NMBG=0
      ICMBG=0
      LTPCST=0
      LMAINC=0
      ICMC=0
      ITCMBG=0
      KHPPL=0
      MSIZEL=0
      MCPFL=0
      TCOSTD=0.
      TICAPD=0.
      TACD=0.
      CCAPD=0.
      CHEADD=0.
      ACDITG=0.
      ACTMBG=0.
      ACMRTG=0.
      ACINTG=0.
      ELECTG=0.
      CLABTG=0.
      TACTG=0.
      TICAPD=0.
      TACEWL=0.
      LCOST=0
C
C
 2000 WRITE(6,2100)
```

```
 2100 FORMAT(≠1≠,//////,9X,≠** DISPOSAL SYSTEM DESIGN PARAMETERS **≠,/,
     *10X,≠========================================≠,//)
C
      WRITE(6,2200)FLAREA,ADP,ADS,MAXDA,DPRATE,XADP,XADS,XPRATE,TSET
     *,PDAYS,ROVOL,MANPOL,DISP
 2200 FORMAT(≠ FEEDLOT AREA= ≠,F17.0,≠ ACRES≠,/,
     1≠ DISPOSAL PLOT AREA= ≠,F14.2,≠ ACRES PER FEEDLOT ACRE≠,/,
     1≠ DISPOSAL SITE AREA= ≠,F14.2,≠ ACRES PER FEEDLOT ACRE≠,/,
     3≠ MAXIMUM DAILY APPLICATION= ≠,F4.0,≠ INCHES PER ACRE≠,/,
     4≠ DESIGN PUMPING RATE= ≠,F13.2,≠ AC.-IN. PER FEEDLOT ACRE≠,1X,
     *≠PER DAY≠,/
     5≠ TOTAL DISPOSAL PLOT AREA= ≠,F8.2,≠ ACRES≠,/,
     6≠ TOTAL DISPOSAL SITE AREA= ≠,F8.2,≠ ACRES≠,/,
     7≠ TOTAL DAILY PUMPING RATE= ≠,F8.2,≠ ACRE-INCHES PER DAY≠,/
     8≠ HOURS REQUIRED PER SET= ≠,F9.1,/,
     *≠ PUMPING DAYS PER YEAR= ≠,F10.1,/,
     *≠ REQD. STORAGE VOL.= ≠,F14.2,≠ AC-IN PER FEEDLOT ACRE≠,/,
     *≠ MANAGEMENT POLICY= ≠,I12,/,
     $≠ DISPOSAL POLICY= ≠,F14.0,//)
C
      WRITE(6,2300)
 2300 FORMAT(7X,≠** INVESTMENT IN EARTHWORK, LAND, AND MISC. ITEMS **≠/,
     *7X,≠====================================================≠,//
     ≥6X,≠-EARTHWORK-≠,25X,≠SIZE≠,12X,≠COST≠,/
     *6X,≠-----------≠,)
C
      WRITE(6,2400)SBVOL,SBCOST,COIV,EXVOL,RPCOST,EWCOST
 2400 FORMAT(≠ SETTLING BASIN≠,21X,F8.0,≠ CU. YDS.≠,1X,≠$≠,F9.0,/,
     *≠ CLEAN WATER DIVERSION≠,32X,≠$≠,F9.0,/,
     *≠ RETENTION POND EXCAVATION≠,10X,F8.0,≠ CU. YDS.≠,1X,≠$≠,F9.0,/,
     *≠ TOTAL COST OF EARTHWORK≠,30X,≠$≠,F9.0)
C
      WRITE(6,2500)LASB,KLASB,LADIV,KLADIV,LARPAP,KLARP,XADS,KLADIS,
     *LATOT,LCTOT
 2500 FORMAT(6X,≠-LAND-≠,/,
     *6X,≠------≠,/
     *≠ LAND FOR SETTLING BASIN≠,12X,F8.2,≠ ACRES≠,4X,≠$≠,I9,/,
     *≠ LAND FOR CLEAN WATER DIV.≠,10X,F8.2,≠ ACRES≠,4X,≠$≠,I9,/,
     *≠ LAND FOR RET. POND AND PERIMETER≠,3X,F8.2,≠ ACRES≠,4X,≠$≠,I9,/,
```

```
     *≠ LAND FOR EFFLUENT DISPOSAL≠,9X,F8.2,≠ ACRES≠,4X,≠$≠,I9,/,
     *≠ TOTAL LAND FOR FACILITIES≠,10X,F8.2,≠ ACRES≠,4X,≠$≠,I9)
C
      WRITE(6,2600)CFENCE,CERP,CDAMS,CENG,CMISC,ICOST
 2600 FORMAT(6X,≠-MISCELLANEOUS ITEMS-≠,/,
     *6X,≠---------------------≠,/
     *≠ FENCING FOR RET. POND≠,32X,≠$≠,F9.0,/,
     *≠ SEEDING EARTHWORKS≠,35X,≠$≠,F9.0,/,
     *≠ CHECK DAMS FOR SETTLING BASIN≠,24X,≠$≠,F9.0,/,
     *≠ ENGINEERING≠,42X,≠$≠,F9.0,/,
     *≠ TOTAL COST OF MISC. ITEMS≠,28X,≠$≠,F9.0,//,
     *≠ TOTAL COST OF EARTHWORK,LAND,MISC.≠,19X,≠$≠,I9,//)
C
C
C
      WRITE(6,2700)
 2700 FORMAT(12X,≠** DISPOSAL SYSTEM INVESTMENT **≠,/
     *12X,≠==================================≠,//
     *18X,≠HAND MOVE≠,3X,≠SIDE-ROLL≠,3X,≠BIG GUN≠,4X,
     *≠MOVING B.G.≠,/
     *18X,≠---------≠,3X,≠---------≠,3X,≠-------≠,4X,
     *≠-----------≠)
C
      WRITE(6,2800)IGPMT,JGPMT,KGPMT,MBGGPM
 2800 FORMAT(≠ TOT. SYS. GPM≠,5X,I8,4X,I8,2X,I8,6X,I8,)
      WRITE(6,2900)NBG,NMBG,LCHM,LCSR,ITCBG,ICMBG
 2900 FORMAT(≠ SPRINKLER UNITS*≠,/,2X,≠NUMBER REQD.≠,
     *27X,I8,6X,I8,/,
     *1X,≠ TOTAL COST≠,6X,≠$≠,I8,3X,≠$≠,I9,3X,≠$≠,I6,
     *5X,≠$≠,I8)
C
      WRITE(6,3000)NPCNT,JPCNT,KPCNT,LPCNT,
     *NGPMP(IPUMP),JGPMP,KGPMP(KPUMP),KGPMP(LPUMP),
     *NHPP(IPUMP),JHPP,KHPP(KPUMP),KHPPL,
     *ITPCST,JTPCST,KTPCST,LTPCST
 3000 FORMAT(≠ PUMPS*≠,/,
     *2X,≠NUMBER REQD.≠,5X,I8,4X,I8,4X,I6,5X,I9,/,
     *≠  DIS. VOL.≠,8X,I8,4X,I8,4X,I6,6X,I8,/
```

```
     *≠  PUMP HP≠,10X,I8,4X,I9,4X,I6,6X,I9,/
     *2X,≠TOTAL COST≠,6X,≠$≠,I8,3X,≠$≠,I8,3X,≠$≠,I6,5X,≠$≠,I8,/)
C
      WRITE(6,3100)KOUNTA,JKOUNT,KOUNTB,KOUNTC,
     *LMAINA,JMAIN,LMAINB,LMAINC,
     *MSIZE(IMAIN),JSIZE,MSIZE(KMAIN),MSIZEL,
     *MCPF(IMAIN),JCPF,MCPF(KMAIN),MCPFL,
     *ICMA,JCMA,ICMB,ICMC,
     *ITCHM,ITCSR,ITCBGS,ITCMBG
 3100 FORMAT(≠ MAINLINE≠≠,/,
     *2X,≠NUMBER REQD.≠,5X,I8,4X,I8,4X,I6,6X,I8,/
     *≠  LENGTH (FEET)≠,4X,I8,4X,I8,4X,I6,6X,I8,/
     *≠  DIAM. (INCHES)≠,3X,I8,4X,I8,4X,I6,6X,I8,/
     *≠  $ PER 100 FT.≠,3X,≠$≠,I8,3X,≠$≠,I8,3X,≠$≠,I6,5X,≠$≠,I8,/
     *2X,≠TOTAL COST≠,6X,≠$≠,I8,3X,≠$≠,I8,3X,≠$≠,I6,5X,≠$≠,I8,//,
     *≠ IRR. INVESTMENT≠,2X,≠$≠,I8,3X,≠$≠,I8,3X,≠$≠,I6,5X,≠$≠,I8,////)
C
      WRITE(6,3200)
 3200 FORMAT(≠1≠,////////////,24X,≠** TOTAL INVESTMENT **≠,/,
     *24X,≠======================≠,/
     *18X,≠HAND MOVE≠,4X,≠SIDE-ROLL≠,4X,≠BIG GUN≠,4X,≠MOVING B.G.≠,/
     *18X,≠---------≠,4X,≠---------≠,4X,≠-------≠,4X,
     *≠-----------≠,)
C
C
      WRITE(6,3300)ICOST,JCOST,ICOST,LCOST,
     *ITCHM,ITCSR,ITCBGS,ITCMBG,
     *TCOSTA,TCOSTB,TCOSTC,TCOSTD,
     *TICAPA,TICAPB,TICAPC,TICAPD
 3300 FORMAT(≠ LAND, EARTH-≠,/,≠ WORK, MISC.≠,6X,
     *≠$≠,I8,4X,≠$≠,I8,3X,≠$≠,I7,4X,≠$≠,I9,/
     *≠ DISP. SYS.≠,7X,≠$≠,I8,4X,≠$≠,I8,3X,≠$≠,I7,4X,≠$≠,I9,/
     *≠ TOTAL INV.≠,7X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,4X,≠$≠,F9.0,/
     *≠ INV./HEAD≠,8X,≠$≠,F8.2,4X,≠$≠,F8.2,3X,≠$≠,F7.2,4X,≠$≠,F9.2,
     *//)
      WRITE(6,3400)
 3400 FORMAT(22X,≠** ANNUAL COSTS **≠,/,
     *22X,≠==================≠,/,
```

```
     *29X,≠SYSTEM≠,/,29X,≠------≠,//,2X,≠ITEM≠,
     *12X,≠HAND MOVE≠,4X,≠SIDE-ROLL≠,4X,≠BIG GUN≠,4X,≠MOVING B.G.≠,/
     *2X,≠----≠,12X,≠---------≠,4X,≠---------≠,4X,≠-------≠,4X,
     *≠-----------≠,//)
C
C
      WRITE(6,3500)ACDIHM,ACDISR,ACDIBG,ACDITG
 3500 FORMAT(≠ DEP. $ INT.≠,6X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,4X,
     *≠$≠,F9.0)
C
      WRITE(6,3600)ACMRHM,ACMRSR,ACMRBG,ACMRTG
 3600 FORMAT(≠ MAINT. $ REP.≠,4X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,
     *4X,≠$≠,F9.0)
C
      WRITE(6,3700)ACTHM,ACTSR,ACTBG,ACTMBG
 3700 FORMAT(≠ TAXES≠,12X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,4X,≠$≠,F9.0)
C
      WRITE(6,3800)ACINHM,ACINSR,ACINBG,ACINTG
 3800 FORMAT(≠ INSURANCE≠,8X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,4X,
     *≠$≠,F9.0)
C
      WRITE(6,3900)CLABHM,CLABSR,CLABBG,CLABTG
 3900 FORMAT(≠ LABOR≠,12X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,4X,≠$≠,F9.0)
C
      WRITE(6,4000)ELECHM,ELECSR,ELECBG,ELECTG
 4000 FORMAT(≠ ELECTRICITY≠,6X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,4X,
     *≠$≠,F9.0,/)
C
      WRITE(6,4100)TACHM,TACSR,TACBG,TACTG
 4100 FORMAT(≠ SUBTOTAL≠,9X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,4X,
     *≠$≠,F9.0,/)
      WRITE(6,4200)TACEW,TACEWJ,TACEW,TACEWL,TACA,TACB,TACC,TACD
 4200 FORMAT(≠ TOT. A.C.≠,/,≠ LAND. EARTH-≠,/,
     *≠ WORK. MISC.≠,
     *6X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,4X,≠$≠,F9.0,/,/,
     *≠ TOTAL≠,12X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,4X,
```

```
     *≠$≠,F9.0,//)
      WRITE(6,4300)CCAPA,CCAPB,CCAPC,CCAPD,CHEADA,CHEADB,CHEADC,CHEADD
 4300 FORMAT(≠ COST PER HEAD≠,/,≠ OF CAPACITY≠,6X,≠$≠,F8.2,4X,≠$≠,F8.2,
     *3X,≠$≠,F7.2,4X,≠$≠,F9.2,//
     *≠ ADD. PROD. COST≠,/,≠ PER HEAD≠,9X,≠$≠,F8.2,4X,≠$≠,F8.2,
     *3X,≠$≠,F7.2,4X,≠$≠,F9.2)
      WRITE(6,4400)
 4400 FORMAT(///,18X,≠ ZEROS INDICATE SYSTEM IS NOT APPLICABLE≠)
      END
```